METALSMITH 1c & CHIEF

NAVY TRAINING COURSES

NAVPERS 10131

METALSMITH 1c & CHIEF

PREPARED BY
STANDARDS AND CURRICULUM DIVISION

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NAVY TRAINING COURSES

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PREFACE

This book is written as an aid in preparation for promotion to Metalsmith 1c and to Chief Metalsmith. Candidates for promotion to either rate are required to read the entire text. Combined with practical experience gained at your duty station, the information in this training course will prepare the reader for advancement in rate examinations.

These examinations are based upon the qualifications for advancement in rating and the qualifications, in turn, are based upon shipboard analyses of the ratings. Qualifications for both rates are printed in the Appendix at the rear of this book and it is suggested that they be referred to frequently. The reader may also wish to review some of the basic Navy training courses, particularly *Mathematics, Use Of Blueprints,* and *Use Of Tools.*

The first two chapters of this book contain general information concerning your work and responsibilities, along with a discussion of safety precautions for Metalsmiths. Following chapters concern themselves with arc welding, gas welding and brazing, construction of ventilation fittings, sheet metal layout and fabrication, and metal testing. The last three chapters are devoted to damage control organization and work.

As one of the Navy Training Courses, this book was prepared by the Training Courses Section in the Bureau of Naval Personnel in cooperation with Naval establishments and personnel specially cognizant of the duties of a Metalsmith.

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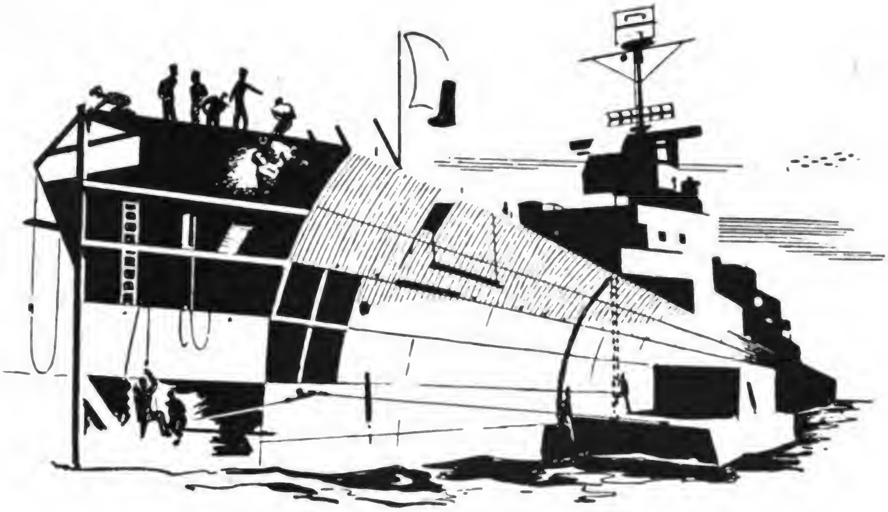

CHAPTER I

THE METALSMITH AFLOAT

GOING UP

Perhaps you haven't noticed it, but as you've been GOING UP in rate and pay, you've also been going up in other ways. With each added stripe you have gained more respect from your mates and have been given more responsibility by your officers and ranking PO's.

You've been going up because you have carried just a little more than your part of the load—because you have done more than you were asked or expected to do. That means you've done a good job of learning and developing the basic fundamental skills required of a Metalsmith.

Up to now your work has been largely with tools. You've developed considerable skill in such operations as welding, brazing, soldering, forging, heat-treatment, coppersmithing, and sheet-metal layout, fabrication, and forming. As M1c and CM you are expected to go even farther. You must develop your skills until you are a top-notch expert—a master of your trade.

As First or Chief you'll assume additional duties, too. You'll have to know the VENTILATING system of your ship, for instance, and not only be an expert in the practices of DAMAGE CONTROL, but also able to organize and lead damage

control parties. You'll have supervisory and training duties, and, as chief, must be thoroughly familiar with all the functions and equipment of the C & R department.

And you'll have to be able to run the metalsmith shop and keep the proper records and reports. Also, as you advance in rate, you'll find that your military duties become more and more important.

RESPONSIBILITY

Naturally, your responsibilities will increase, too. Instead of being TOLD what to do, you'll be more and more responsible for TELLING other men WHAT to do—and, often, HOW to do it. Telling only isn't enough. You'll have to see that the job is done right. This may mean SHOWING your men how to do the job and checking the job after it has been done.

You may become the leading petty officer of your rate aboard ship. As such you'll be the engineering officer's right hand man as far as metalsmith work is concerned. It also means that you'll be his right hand man for organizing, supervising and instructing other men in their military duties as well as in their specialties.

SHIP ORGANIZATION

You've already discovered that a ship's company is a highly organized unit. Every man's job, from that of the Captain to that of the newest recruit, has been studied and analyzed so that the whole organization will be as perfect as possible in every detail.

As M1c or CM you'll be an important cog in the organization. If you are assigned to new construction you may be asked to help work out some of the organization bills for the hull and engineering departments of the ship. Or you may be made responsible for the efficient organization and management of a welding or sheet metal shop.

Whether you're running a shop or not, if you're a CM you'll have to be able to estimate and plan TIME, COST, and MATERIAL for any C & R metal repair job or alteration. That's something you can learn only by experience. Figure carefully—don't forget the little details.

SUPERVISION

When you're in charge of a shop or activity involving metalsmith work, you'll supervise strikers and lower-rated Metalsmiths. It will be your job to assign work to your men and to see that it's properly completed.

You'll inspect all work turned out by the men under your supervision and make suggestions for the improvement of any that's inferior or unsatisfactory. For the sake of your ship's well-being—and the sake of your own reputation—never allow a job of inferior quality to leave your shop.

INSTRUCTION AND TRAINING

Most of your instruction work will be in the form of actual shop practice in welding, brazing, sheet metal work and other metalsmith activities. Your instruction on military duties will be mostly in the form of drills. You're expected to be able to lead discussions, deliver short lectures and give demonstrations on technical phases of both specialties and military duties.

Figure 1.—Metalsmiths at work.

PAPER WORK

Properly operated shops require considerable paper work—records, reports, work requests, inventories and work-progress

forms and charts. If you are in charge of the shop it's your duty to see that this work is done properly and kept up to date. That means you'll have to do it yourself or delegate one of your men to keep track of it.

You may be allowed to set up your own office organization

Figure 2.—Can you direct the repairs to this damaged flight deck?

or it may be set up for you by your division officer or by the engineering officer. The ship will have standard forms and blanks for keeping some of the required records and for making certain transactions. These you can supplement as required.

Keep all your records up to date. Know what is going on in your shop at all times. Efficient paper work will enable you to keep a close check on each job and on each workman under your supervision.

YOUR SKILL AND KNOW-HOW

As a First or Chief, you're expected to be able to do any job that may be required of a Metalsmith—welding, brazing, forming, coppersmithing or drawing patterns for complicated transition pieces. You can not expect to command the respect of your men and your officers unless you can perform the work of your rate in a skillful manner.

You must also understand the operation and use of all

machinery under the C & R Department. Maintenance is the problem of the machinists and electricians, but nevertheless KNOW YOUR MACHINES. Read the BuShips Manual and manufacturers' instruction books. For additional details see the training courses for carpenters and shipfitters.

It's up to you to keep up with the latest information not only about your machinery, but about such items as brazing rods and fluxes, heat-treatment methods, hard-facing alloys and bronze-build-up work. Your men will depend on you so don't let them down. KNOW YOUR STUFF.

CHAPTER 2

SHOP MANAGEMENT AND SAFETY

TRAINING IN THE SHOP

Aboard ship there may be times when Metalsmiths will be required to work 16 or 18 hours per day on rush jobs. At other times you may have nothing but routine work for several days at a stretch. That's when you'll find time to TRAIN your men.

When equipment in the shop is not required for regular work, assign some practice jobs to your strikers and lower-rated men. Give them a chance to learn new skills. Such training should be WELL-PLANNED—by you—so that the men will acquire the maximum amount of knowledge and skill in the minimum time.

Avoid hit-or-miss methods of teaching. Don't say to a man, "Don't you think it is about time you practiced some welding?", and then forget all about him as soon as you see that he has the torch lighted. Give him some DEFINITE JOBS to do—jobs of increasing difficulty that will improve his welding ability. Then keep tab on his practice. Give him all the help you can, and check his work as he goes along.

Pay particular attention to training the man who is weak in one or two phases of his work. If a man lacks skill in sheet metal work, give him a chance to practice it alongside a skilled sheet metal worker.

When an unusually difficult job is going to be performed by one of your highly skilled men, call in some of the other men to watch him. This is a valuable training method and a well-deserved compliment to the man you have selected to do the job.

JOB ASSIGNMENTS

If you're in charge of a shop or of the metalsmith work done in a general shop, you're the man who will assign the jobs to rated men and strikers working under your supervision. The making of such assignments should receive careful thought on your part.

Jobs to be done in a shop will include gas and arc welding, brazing and silver-soldering, pipe-threading, pipe-bending, sheet metal layout, sheet metal fabrications, bending, shaping, riveting, soldering, and others. Avoid having a man do all work of one type just because he happens to be an expert in that particular phase of metalsmith work. Pass the work around so that each man will get a chance to develop his skill in all phases. Assign your strikers to assist with various kinds of work so they'll also get some experience on all kinds of jobs.

Rotating assignments makes the work more interesting for the men and, in addition, makes them better qualified for advancement in rating. Another good reason for rotating assignments is that if one highly skilled man does all the work of a certain type, you and your ship will be at a great disadvantage should he ever leave the crew.

SHOP BOOKS

One of the first things a first-rate Metalsmith does when he reports aboard a ship is dig down in his sea bag and bring out his books on welding and sheet metal work. Every good Metalsmith should have for his own use, several good reference books about these and other subjects in the field.

Loan your books to the men who work with you and encourage them to loan their books to each other. Establish a small library in your shop if you can. One or two welding books and some on sheet metal fabrication and layout should form the backbone of such a library. Other books about coppersmithing, forging, brazing, pipefitting and heat treatment should be added if possible.

Catalogs, pamphlets, and circulars from commercial companies provide valuable instructional material. You can obtain such material by writing to the companies that made your welding equipment, pipe fitting equipment, electrodes, fluxes, metal stock, tools, valves, pumps, and so forth.

Included in your shop library should be copies of such Navy publications as *Use of Blueprints, Use of Tools, Basic Machines,* and *Mathematics,* all of which are BASIC training course books prepared by the Bureau of Naval Personnel. The Bureau of Ships issues a series of technical publications on such subjects as VENTILATION and DAMAGE CONTROL. The same bu-

Figure 3.—Teaching arc-welding by demonstration. Note that the men wear shirts with long sleeves.

reau publishes a "Guidebook to the Use and Supply of Welding and Brazing Materials for the Naval Service." You can obtain these various books by asking your educational officer (or division officer) to request them through the proper channels. Books setting forth welding specifications are also available and easily obtained.

Get some help from your officers when setting up your shop library. The officers to see are your Division Officer, the Training Officer or Educational Officer, and Warrant and Chief Warrant Carpenters and Machinists. Its always a good idea to visit another ship for helpful suggestions.

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JOB ORDERS

Work passing through your shop and other shops aboard is handled by forms which are usually called JOB ORDERS. Various forms may be used on different ships but they will contain essentially the same information as the one shown in figure 4, which is a type used by a light cruiser. This cruiser has a Hull Department, rather than separate C & R and Engineering Departments.

U.S.S. FANTAIL REPAIR File No.	URGENT ROUTINE DEFERRED	BUREAU	SHIP'S FORCE BEYOND CAPACITY OF SHIP'S FORCE
Index Class.	Unit & Location		Requisition or Plan No.

(Do not write above this line.) Give brief of repair below. List applicable blue prints or attach sketch. Give all necessary data on material and dimensions. Use back of card if necessary. Type in duplicate.

Date...................... ....
Head of Dept.

(Do not write below this line)

Status of Material.		
Bd. of I. & S. Forces Aflt. Natl. Insp.	Item No.	Title and File No. of Inspection Report Date

Requested in Ship's Work List	J. O. No.

Estimate	Approved	Started	Completed	Man Hrs.	Ent'd in Record Date Initial

Figure 4.—Job order form used by light cruiser.

A job order form is filled out by the officer—usually the department head—who wants the work done. He fills in the upper part of the form, including a detailed description of the work desired, necessary sketches, dimensions, blueprints, fittings, materials, and so forth. He signs the form and sends it to the office of the FIRST LIEUTENANT. This officer checks the

job order, approves or disapproves it and sends it to the shop which will do the work.

The spaces at the bottom of the chit are filled in by men assigned to the office of the First Lieutenant. The ship's Carpenter or Chief Carpenter makes the entries in those marked *Started, Completed* and *Man Hours.* On some ships, if you are assigned to the Engineering Department, these spaces will be filled in by the Machinist or Chief Machinist.

No work or jobs should be done by men in the shop without the specific authority of a job order. If you skip getting the proper authority in the form of the job order, you'll only cause confusion and trouble. Get the job order BEFORE YOU START.

Current job orders are usually kept on a clip-board until the work is completed. They are checked by the W.O. in charge, marked when completed, and returned to the office of the First Lieutenant where they are logged in the HULLBOOK. The hullbook is a log of the work done in each compartment of the ship.

SHOP LOGS OR NOTEBOOKS

Shop logs or notebooks are kept by the petty officer in charge of a shop or activity. One log is kept for WORK PROGRESS. It's a record of all work done by that shop, and by each man assigned to the shop or working force. Another log is used to keep track of materials and supplies expended and tentative lists of such items that should be requested when a source of supply becomes available.

Material sufficient to cover the needs of the next three months is usually kept on hand. Lists of DESIRED MATERIAL, made up from notes in the shop material log and by estimating needs, are furnished the Carpenter or Machinist by the petty officers in charge of each shop or activity. The Warrant Officer, in turn, presents the list to the First Lieutenant or to the Chief Engineer who requests the Supply Department to secure the desired material. On receipt of material, it is checked by the cognizant Warrant Officer and the petty officers under his supervision.

SHOP HOUSEKEEPING

You can give a workshop one good look and tell whether it's efficient and well-run. Just make a quick survey for

cleanliness, neat tool and stock stowage, and the condition of equipment. If such a survey reveals a high quality of HOUSE-KEEPING, you can bet that it's a well organized shop that really turns out the work.

Tool stowage is an important item in the shop. As you know, lockers, racks, drawers, cabinets and boxes are used for stowing tools. The place selected depends largely on the USE of the tool, the FREQUENCY of its use, its SIZE and SHAPE, and its VALUE.

Drill bits, micrometers, torch tips, combination squares, files, gages and the like must be stowed so they are protected from contact with other tools. Edge tools and pointed tools, such as scribers, dividers, and compasses, require special stowage to prevent damage to cutting edges and sharpened points.

Precision tools, such as micrometers, depth gages, surface gages, squares, etc., must be protected against SHOCK, or PRESSURE. All tools made of steel must, of course, be protected against CORROSION.

Particularly valuable and hard-to-get tools—usually Title B—should be kept locked in special lockers, drawers, cabinets or toolboxes. These include portable power tools, gages and micrometers, and special pliers, wrenches, files, drills, etc. Most of these tools are seldom used by the Metalsmith, but when they are needed, they are indispensable, hence the special care.

Material and supplies—welding rods, electrodes, flux, solder, screws, bolts, sheet and plate stop, pipe, bars and other shapes, hinges, gasket material—must be stored in a convenient, secure and orderly place. Use cabinets, shelves, bins, and racks, located so as to allow the greatest possible amount of free working space in the shop.

Tools frequently used OUTSIDE the shop should be made up in KITS and stowed in convenient toolboxes.

If shop space permits and a sufficient number of tools are available, each rated man should have his own stowage drawer and toolbox in which he can keep the tools he ordinarily uses. No man likes to use a drill bit that someone else has nicked or burnt, and each likes to have his own hammer, chisels, or square.

If space permits, one corner of the shop may be blocked off for use as a TOOL ROOM in which such tools as portable power drills and grinders, bolt cutters, welding torches, grinding wheels, large dividers, pipe wrenches, C-clamps, large drill

bits, special files, dies, taps, tap wrenches and die stocks can be kept. A striker should be made responsible for keeping the tools in order and issuing them as required. This toolroom job should be rotated among the strikers to give each man an opportunity to learn the names and uses of all the tools.

Tools used in your shop may be marked with a distinctive COLOR for identification. If so marked they are not as easily mixed with tools from other shops or with tools that belong in damage control and repair lockers.

It's usually a poor policy to loan tools from the shop. If the use of a tool is necessary, one of the Metalsmiths should be the man to use it.

Good housekeeping requires that bench tops, power equipment and the deck be kept clear of unnecessary tools and material, scrap stock, filings, dirt, and excess oil and grease.

CARE OF PNEUMATIC TOOLS

Metalsmiths may use or supervise the use of pneumatic CHIPPING HAMMERS for chipping paint and rust, removing rough metal edges and preparing edges for welding. You are also responsible for the CARE of these tools.

Keep the tool clean. Do not remove the air intake screen of a pneumatic tool except for cleaning. Lubricate with special oil or a fine oil such as SAE #10. Working parts of the tool should be lubricated after EACH HOUR of operation. Store the entire tool submerged in a bath of fine oil if possible.

The ideal working pressure for an air hammer is 90-100 psi (pounds per square inch). See that your men wear gloves and goggles when they are operating these tools. The hammer should be held so that the hands are directly over the top of the chisel. Always remove the chisel when it's not in actual use. Fingers should be kept BEHIND or UNDER the trigger when the tool is not in operation.

Pneumatic AIR DRILLS are of two types—piston and multiple vane. Avoid excessive lubrication of the multiple vane drill. This type is preferred for many jobs because its speed is controllable.

PORTABLE ELECTRIC TOOLS

Portable electric drills and grinders require little maintenance. Oil such tools by the methods and at the frequencies suggested by the manufacturer.

Electric tools are often damaged by careless handling of the power cable or cord. Always disconnect them by pulling ON THE PLUG—not by jerking on the cable. Never carry the tool by the cable and avoid kinks which tend to separate the strands of the cable.

PRECAUTIONS FOR SAFETY

It's your responsibility to see that all work done by your men, both in the shop and on outside jobs, is done in a safe manner. The primary safety precautions are SAFETY OF PERSONNEL and the SECURITY OF THE SHIP. In addition, doing work by safe methods and practices will help to prevent unnecessary wastage of material and undue damage to tools and other equipment.

Carelessness is the greatest single cause of accidents. Comparatively few accidents can be traced to the mechanical failure of machines, tools and equipment. It's your job to teach your men to follow safety precautions and rules, and to use safety devices.

HOT METAL—as you may well know—has been the cause of many a bad burn. Such burns were usually the result of forgetfulness or carelessness, or because someone believed "the metal wasn't hot". Consider all metal as being hot until proved otherwise. The best safety precaution against hand burns is the wearing of suitable asbestos or leather gloves. In addition, hot metal should be well advertised as such.

ACID BURNS are extremely painful. They can be prevented by careful stowage, handling and mixing. Remember—when acid and water are being mixed, the acid should be poured INTO the water. If you do get acid on you, douse it with plenty of water at once—in other words, DILUTE it. And keep acids safely stowed away except when they are in actual use.

Eyes are extremely vulnerable to acids and should be protected by clear-lens goggles when acid is being handled or mixed. If much handling of acids is required of a man, he should be provided with rubber gloves, respirators and special protective clothing.

Be careful of breathing in POISONOUS FUMES from acids and fluxes, or from heated metals which contain lead and zinc. Breathing fumes from zinc may bring on a kind of chill known

as the "zinc shakes". Such poisoning may be counteracted to some extent by drinking plenty of sweet milk.

The obvious—and best—safety precautions against poisonous fumes is to get rid of them. Adequate VENTILATION should be provided before the work begins, particularly for those operations involving the heating of non-ferrous metals and alloys, brazing rods, electrodes, solders and fluxes.

COMPRESSED BOTTLED GASES, especially those used for welding and cutting, are dangerous when used and handled carelessly. Detailed safety precautions for the handling and use of acetylene and oxygen are covered in the Navy Training Course for Metalsmith 3c and 2c and in other Navy publications.

Figure 5.—Metalsmiths at work. Note the cleanliness and neatness of the shop.

INFLAMMABLE SOLVENTS, such as gasoline, benzine, naphtha and alcohol, must be handled with the greatest of care. Navy Regulations prescribe the maximum amounts of these solvents that may be kept in the shop. Containers for such solvents must be leakproof and fume-tight and should be kept as far as possible from welding and heating equipment.

Keep excess oil and grease off decks and bench tops. Use only enough oil to prevent rust. Oily and greasy rags and waste should be placed in fireproof containers and properly disposed of at the end of each working period. Remember

that oil or grease must NEVER be used on any item of welding equipment. Stores of oil and grease should be removed from the vicinity of welding and cutting operations.

Cored castings and other COMPLETELY ENCLOSED spaces in metal structures, will EXPLODE when heated if they are not properly vented. Threaded removable plugs are provided in some structures. These must be removed before any kind of heating, such as that required for welding or annealing, is begun. Drilled holes will provide vents for structures that do not have threaded plugs. When the heating is completed and the structure has cooled, the drilled vent holes can be threaded and filled with tight-fitting studs.

THERE IS NO SAFE METHOD OF HEATING A COMPLETELY ENCLOSED STRUCTURE—ADEQUATE VENTS MUST BE PROVIDED. Beware of objects which seem to weigh less than you think they should. The probably contain enclosed spaces.

EXPLOSIONS may occur if wet sand is used to pack pipes for hot-bending operations. Use only DRY SAND when pipes are packed for bending. The moisture in wet or damp sand will turn to steam when the pipe is heated. The pressure exerted by the steam may be great enough to burst the pipe with a violent exploson. So the sand must be DRY and—as added insurance—VENT HOLES should be drilled through the pipe-end plugs.

Cuts are often the result of careless handling of sheet metal and shapes which have sharp, jagged edges, ends and corners. Insist that your men wear gloves and work carefully when they are handling such material. Burrs should be removed from sheet metal edges before layout and fabrication. If a man does get a cut, it's your responsibility to send him to sick bay IMMEDIATELY and to report the accident to the proper authority.

Careless use of machines, particularly sheet metal cutters, is often the cause of serious accidents. Such machines are ordinarily provided with adequate guards and other safety devices. Make sure those guards are in place and that they are used.

Tools and other objects adrift on deck or bench can also be the cause of serious accidents. Don't allow such objects as scraps of metal, wood scraps, tools, screws, nails, bolts, nuts, washers, rivets, welding rods, flux cans and electrodes to float around in the shop. Keep each item in its assigned place.

"Traffic" accidents sometimes occur on board ship when

heavy pieces of equipment, such as arc-welding and gas-welding outfits, are moved from deck to deck. The men assigned to move such equipment should be made to feel responsible for its safe handling. Always assign a sufficient number of men to such jobs to prevent overloading, straining, or damage to equipment.

Long objects, such as pipe sections, should be carried by TWO men, one at each end. Each man should hold the pipe at the extreme end to prevent the ends from striking or punching personnel or equipment.

Welding gas bottles should be transported from deck to deck in special cradles that will help prevent damage to bottles and regulators.

Figure 6.—Protect your eyes by wearing goggles.

Tools that are in poor condition cause accidents as well as unsatisfactory work. Tool handles should be strong and sound, firmly secured to the tool and free of dirt, oil and grease. Metal-cutting tools should be kept sharp and properly ground. Mushrooms should not be allowed to form on the heads of chisels and punches.

Use of the WRONG TOOL on a job may also cause an accident. A tool should be used only for those jobs for which it is designed and intended.

FIRES are often started because of thoughtless and careless handling of such heating equipment as oxyacetylene, gas, and

alcohol torches, soldering coppers and electric arc. These items of equipment should never be used near any inflammable material or when inflammable gases are present in the air of the working spaces and adjoining spaces.

Eye accidents are easily prevented by the use of suitable goggles. Approved types of goggles should always be used for welding, brazing, chipping, grinding, forging, and similar operations. In addition, all GUARDS that are furnished with machines should be kept in place at all times.

When arc-welding, a workman should not be allowed to STRIKE AN ARC without his face mask in place. Other personnel within 40 feet of the arc should be warned NOT TO LOOK AT THE ARC without using face masks. Arc-welding screens, made of fire-resisting material, should be used if available. They screen the arc and protect personnel and material from flying sparks and spatter.

Protective clothing—special gloves, shoes, coats, pants, helmets and aprons—should be available for the use of those men who do considerable work involving welding, brazing and cutting. It's your responsibility to see that this equipment is available and that it is used to protect personnel and maintain the security of your ship.

Your motto should be "SAFETY FIRST, LAST and ALWAYS."

CHAPTER 3

VENTILATION

YOU HAVE IT

If you'd been one of the crew of a square-rigger about 1779 your only means of getting a good whiff of fresh air would have been by sticking your head through a hatch in a weather deck. In those days it was plenty stuffy below decks. The air was damp, stale and foul—particularly when all hatches were battened down during a storm. And, if the hatches were left open to allow a few breezes to stray in, the air was usually too hot, too cold, or too wet.

The air supply situation has changed considerably since the days of John Paul Jones. Modern ships have VENTILATION SYSTEMS which supply fresh air and remove or exhaust the stale air. The fresh air supply is warmed when necessary. Some spaces, such as the radio room and I.C. room, even have special units which cool and recirculate the air supplied by the regular ventilation system.

All modern fighting vessels depend almost entirely on FORCED ventilation. As a Metalsmith, one of your many jobs will be to lay out and plan replacement parts and fittings for the venilation systems of your ship. You may even be required to design, plan, and lay out new lines and systems.

You won't be able to do a thorough job of ventilation work

unless you understand the design and purpose of the various fittings and duct sections that make up a VENTILATION RUN.

The composite drawing in figure 7 shows the general layout and run of one SUPPLY SYSTEM and one EXHAUST SYSTEM for a modern cruiser or battleship. Refer to this illustration as you read the rest of this chapter.

VENTILATION SUPPLY SYSTEMS

To preserve the watertight integrity of the vessel, shipboard ventilation is divided into MANY SMALL systems. A battleship, for example, has over twelve miles of ducts which are divided into as many as 150 separate systems. Some of these systems are supply and others exhaust. Each system is individual and works independently of the others. None of the systems are interconnected.

A SUPPLY ventilation system is designed to serve a certain group of compartments and spaces with an adequate amount of fresh air. The air enters the ship through a standard type of waterproof VENTILATION INTAKE, located on or above the main deck or in a deckhouse bulkhead. From the intake the air passes through a vertical duct known as a TRUNK, which is usually built as part of the ship's structure.

The trunk leads through the main deck to the FAN which provides the suction to pull the air into the intake and down the trunk. An air PREHEATER, with controlling THERMOSTAT, is connected between the trunk and the fan. This heater is often removed when extra heat is not required. In that case, the heater is stored and plain duct section installed in its place.

The fan is the heart of the ventilation system. The types of fans are known as CENTRIFUGAL and VANEAXIAL fans. The vaneaxial fan is preferred for supply systems because it requires a shorter run, takes up less space, saves weight, cuts down noise, and lowers resistance losses. Note the differences as shown in the Figure 8.

The fan pulls in the air by suction and then pushes it on through the system. First it goes through a MAIN, then through branch mains, and finally through smaller branches. At the end of the line the air is delivered through end openings known as SUPPLY TERMINALS.

PREHEATERS are often located in the branch mains to serve individual spaces or compartments. DAMPERS are installed in terminal fittings. They can be manually operated to control

the amount of air ejected through the supply terminals.

WATERTIGHT CLOSURES are installed in ventilation runs to prevent flooding and to provide watertight integrity. Some of these closures are automatic-check valves and others are manually operated-gate valves.

RATPROOF and INSECTPROOF SCREENS are used over intakes and supply terminals only when necessary, for their use reduces the output efficiency of the system. SPOOLS—similar to piping spools—are used where the ventilation run penetrates bulkheads and decks.

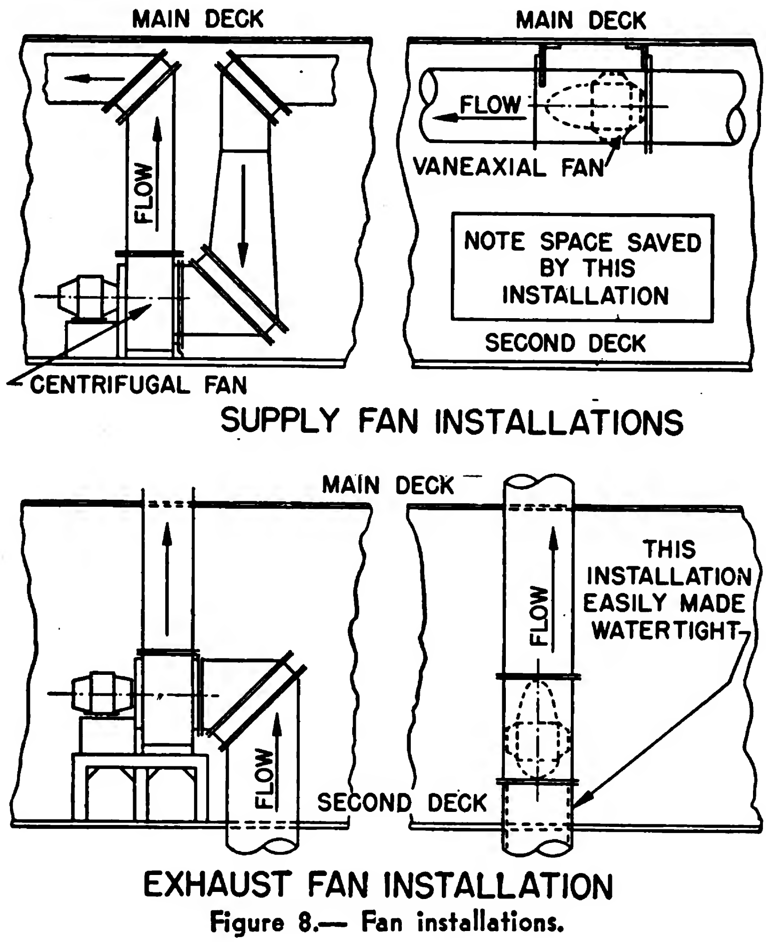

Figure 8.— Fan installations.

ARMOR GRATINGS or VENTURI TUBES must be used when armored decks are pierced. You won't cut any holes in armored decks but you might be called on to repair a damaged venturi tube or remove and replace an armor grating.

The size of supply system ducts is based on the size and number of compartments and spaces served by the system. Ventilation design engineers calculate the supply requirements of

each space in terms of cubic feet of air per minute. The total requirement for all openings—terminals—determines the size of the main, branch mains and branches, and the capacity of the fan.

Branch mains and branches are designed to proportion the air properly to BALANCE the system; in other words, to provide each space with its fair share of the air supply.

A sample supply system is diagrammed in figure 9. The DESIGNED output is shown with the CIRCLED figures; the ACTUAL output in LARGE figures. Ventilation standards require that each terminal supply a minimum of 90 percent of its designed output. Inspectors check the supply output with instruments such as anemometers, velometers, pilot tubes and differential pressure gages.

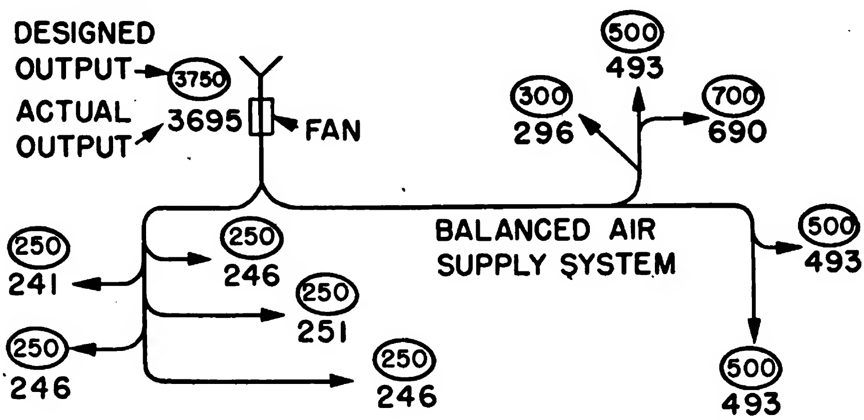

Figure 9.—Diagrammatic sketch of a balanced supply system.

Because each supply system is scientifically designed and balanced, you can't just add on another branch anywhere you please. If you did you would foul up the whole system.

Occasionally some bright guy conceives what he fondly thinks is a brilliant idea and chops a hole in a ventilation duct to provide his bunk with individual ventilation. By so doing he not only unbalances the system but also endangers the watertight integrity of the ship. That's bad—so bad that it's a COURT MARTIAL OFFENSE to cut a hole in a ventilation duct. Pass the word along.

EXHAUST VENTILATION SYSTEMS

Stale air and fumes from living spaces, galleys, messrooms, heads, paintrooms, magazines and handling rooms are removed by EXHAUST SYSTEMS. Ordinarily the exhaust system serves

the same spaces and compartments that are served by one supply system.

Closures, fans, venturi tubes, armor gratings, branches, ventilators and some other fittings are similar for both supply and exhaust systems. The most important differences in the two are—

VANEAXIAL FANS (mounted vertically) are preferred for exhaust systems but they cannot be used if the exhausted air might contain inflammable or explosive vapors or fumes; CENTRIFUGAL fans (see figure 8) must be used to exhaust such fumes and vapors.

Exhaust BRANCHES running from magazines, paint rooms, etc., must be provided with INTERNALLY mounted flameproof screens. DUCTS and fittings for exhaust must be designed and constructed to provide minimum resistance to air passing OUT of the ship. Preheaters and reheaters are NOT placed in exhaust lines.

DUCT DESIGN

A run of ventilation piping is known as a DUCT. It is made up of standing fittings and DUCT SECTIONS which are fabricated and installed by the shipbuilders. You may have to repair or replace some of these sections and fittings.

There are several important considerations which shipbuilders must keep in mind when designing, fabricating, and installing ventilation ducts. First is the WATERTIGHT INTEGRITY of the compartments and spaces served by the ventilation system.

Watertight integrity is particularly important for branches that extend to lower decks and platforms. Penetration of watertight and armored decks and bulkheads is avoided as much as possible. Ducts passing through such boundaries must be watertight and contain the specified closures and fittings. They are of welded construction. Figure 10 shows how ventilation ducts are placed to maintain watertight integrity.

Streamlined DUCT INTERIORS are necessary because the ducts must move air efficiently, with minimum loss from seams, joints, turns, and fittings. Reinforcements and stiffeners, when required, must be placed on the outside of the duct.

Noise must be held down. Seams, splitters, dampers, vanes,

and terminals must be designed so that air can flow quietly over and around them. Otherwise you'll get nerve-racking whistles and groans when you turn on the fan. When flowing air hits a sharp edge it has the same effect you get when you blow on the reed of a harmonica or clarinet.

Headroom and space limitations must also be considered. Round ducts offer the least resistance to moving air so they are used when space permits. Rectangular sections are used where space limitations prohibit the use of round sections.

Lastly, supply ducts should not have terminals which discharge air toward electrical installations. The salty moisture in the air will cause such equipment to deteriorate rapidly.

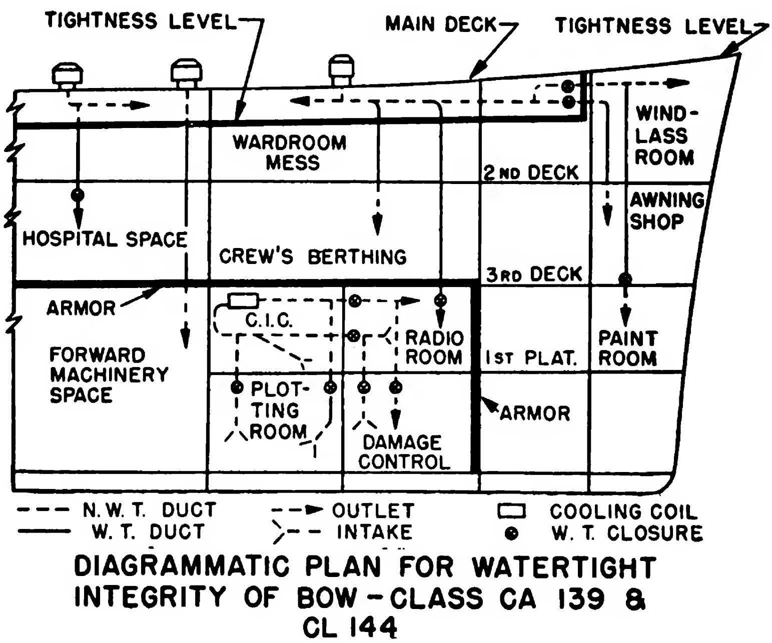

Figure 10.—Duct and closure principles for watertight integrity.

Branch mains take off from mains, and branches take off from mains or branch mains, at angles varying from 30° to 90°. Duct SPLITTERS and SCOOPS proportion the air to branch mains and branches. Don't monkey with splitters in existing lines unless ordered to make repairs. The splitters are set and secured in the correct position by the shipbuilders.

It is not permissible to run ducts through square or rectangular openings in decks, bulkheads, beams, or girders. Such holes must be round, oval, or flat-oval in shape or they will decrease the structural strength.

DUCT MATERIALS

Ventilation duct sections are made of galvanized steel, unless other material, such as aluminum or corrosion-resisting steel, is specified.

Watertight duct sections must have a minimum wall thickness of 0.095 inch. All ducts that pass through compartments subject to pressure tightness tests must be strong enough to withstand the testing pressure.

For making or repairing NON-WATERTIGHT ducts and fittings made of galvanized steel you should use metal of the thicknesses specified in figure 11.

THICKNESS OF GALVANIZED STEEL FOR DUCTS

SIZE OF DUCT (diameter for round ducts; longest side for rectangular ducts)	REQU'D THICKNESS (zinc coating increases thickness about one gage)
6″ and under	0.019″
Above 6″ and including 8″	0.025″
Above 8″ and including 12″	0.031″
Above 12″ and including 18″	0.038″
Above 18″ and including 30″	0.050″
Above 30″	0.063″

Figure 11.—Thickness of metal for non-W.T. ducts.

FORMING ALLOWANCES FOR DUCT SECTIONS

The layout and construction of either round or rectangular straight duct sections is comparatively simple IF you calculate your ALLOWANCE correctly. After all, a duct section won't be satisfactory unless it FITS inside the flange opening.

What happens to a piece of flat sheet metal when you form it into a cylinder for a round duct section? That's right—it STRETCHES on the outside and SHRINKS on the inside. These changes have little effect when you're working with thin metal, but it's a different story when you're using the heavier gages. To make the necessary allowances for forming follow these directions—

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For stretch-out of a ROUND section with an inside diameter of 6 inches, just add the THICKNESS of the metal to 6 inches and multiply by pi (3.1416). The answer is your stretch-out dimension. This system works for any diameter of duct. For the stretch-out of any RECTANGULAR duct which must have a specified inside measurement, just add the THICKNESS of the metal to EACH of the four sides.

Flanges are usually made to fit OVER ducts of specified inside diameters. In other words, a round flange for a 3 inch duct has an inside diameter of 3 inches PLUS twice the metal thickness, PLUS a slight additional allowance (usually 1/16 inch) for clearance.

When you're making a round or rectangular flange you can use the allowance formulas for sheet metal.

SEAM ALLOWANCES

Round sections made of thin metal (20 to 26 gage) may be assembled with GROOVED SEAMS. The grooving guide, figure 12, is to be used in conjunction with these seams.

GROOVED SEAM GUIDE

Material thickness	Total Seam allowance	Amount of turn-up	Hand groover size number	Width of groover slot
0.019	3/4"	1/4"	#2	5/16"
0.025	3/4"	1/4"	#2	5/16"
0.031	13/16"	1/4"	#1	11/32"
0.038	13/16"	1/4"	#0	3/8"

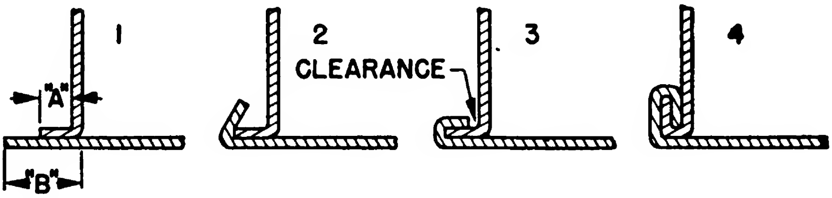
Figure 12.—Grooved seam guide.

Round ducts made of heavier metal are LAPPED and then riveted with tinner's rivets. The lapped surfaces are tinned before riveted and then sweated together after riveting. Total lap allowance—landing—is usually 3/4 inch to 1 inch.

Rectangular ducts may be riveted but are usually assembled with DOUBLE SEAMS. The four steps in forming a double seam are shown in figure 13. Pittsburgh locks are used occa-

sionally but are not as strong as double seams.

EDGE ALLOWANCES for double seams for various thicknesses



REFER TO DOUBLE SEAM TABLE FOR ALLOWANCES "A" AND "B"

Figure 13.—Forming a double seam.

of sheet metal are specified in figure 14. Refer to figure 13 when using these allowances.

DOUBLE SEAM ALLOWANCES

Metal Thickness	Allowance "A"	Allowance "B"
0.019"	7/32"	15/32"
0.025"	1/4"	17/32"
0.031"	9/32"	19/32"
0.038"	5/16"	21/32"
0.044"	3/8"	13/16"
0.050"	3/8"	7/8"
0.062"	7/16"	15/16"

Figure 14.—Double seam allowances.

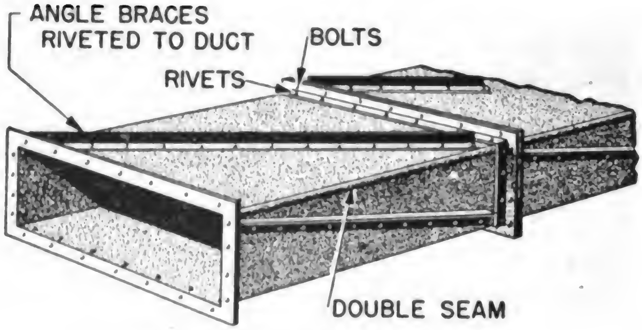
STIFFENERS FOR RECTANGULAR DUCTS

The walls of large rectangular ducts sometimes vibrate under air pressure. This vibration kown as PAINTING, is minimized by angle STIFFENERS riveted to the outsides of the ducts. Figure 15 shows you how to install these stiffeners. No stiffeners of any kind are to be placed INSIDE a duct.

AROUND THE CORNER

TURNS in air ducts are usually avoided, but some are necessary. Until recent years most turns were of familiar "elbow" or "radius turn" type for both round and rectangular ducts. Now the trend is toward VANED turns. The design and construction of these turns has been standardized by BuShips. You may requisition made-up vaned turns for repair or replacement work. Only in an emergency will you have to make one.

A vaned turn is made up of a flanged GRID and a suitable number of curved vanes. The necessary information for making 3 inch grids for 90° vaned turns to fit rectangular ducts is



MAIN DUCT STIFFENERS

Figure 15.—Installation of rectangular duct stiffeners.

given in figure 17, just in case you do have to lay out and make one. Weld the vanes in place.

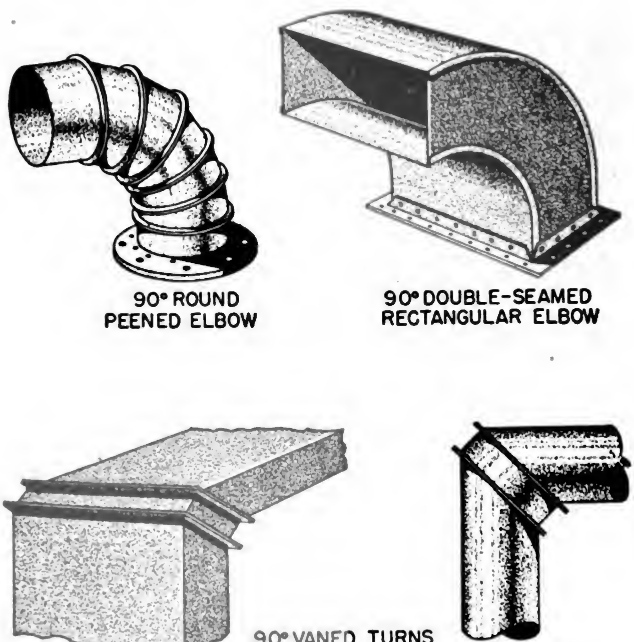


Figure 16.—Elbows and vaned turns.

TEES AND TAKE-OFFS

Ordinarily when a branch takes off from a main, the size of the main is reduced where it extends past the TAKE-OFF. This

is also true of a branch main that has a branch take-off. The REDUCER connecting the two sections is the proper place to locate the take-off. A central or concentric reducer, with a take-off, is illustrated in figure 18. It's used with either supply or exhaust systems.

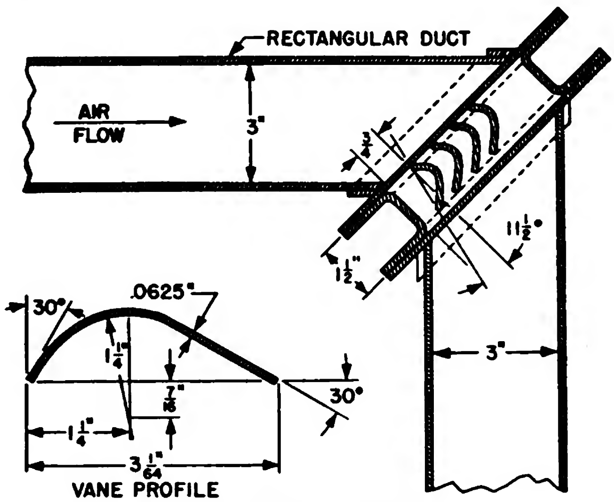


Figure 17.—Design for 90° vaned rectangular turn.

Rectangular TEES which connect two branch mains to the end of a main duct are constructed as shown in figure 19.

OFFSET TAKE-OFFS are used to take off branch mains from mains. With appropriate vaned turns, the branch main can be

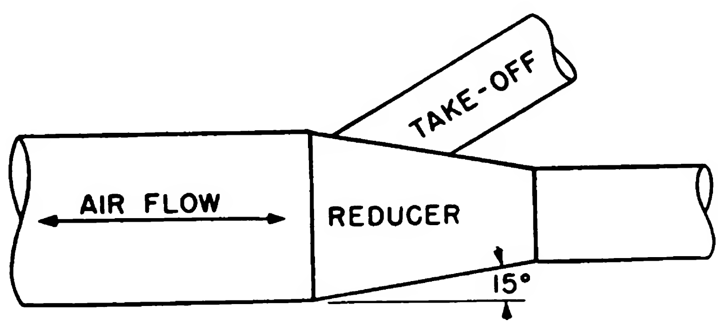


Figure 18.—Central reducer with take-off.

taken off at angles of 30°, 45°, 60°, and 90°. The branch main shown in figure 20 is taken off at an angle of 90°. Notice the SPLITTER. It balances the amount of air directed into the branch main. The splitter is usually made so that it is adjustable, but after its correct location is determined, it is riveted in place.

Small round branches are often taken off branch mains at 30° angles as illustrated in figure 21. Notice the SCOOP, which can be used to feed air into the branch. A scoop of this type may be installed in any round branch if the next flanged section is removed.

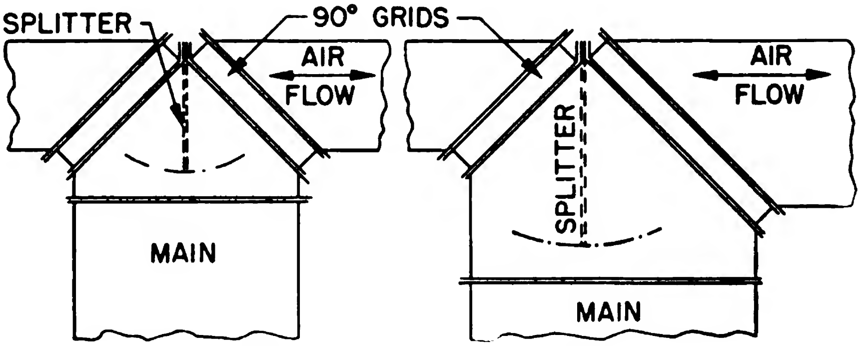


Figure 19.—Rectangular tees.

The take-offs shown in figures 18 to 21 work satisfactorily with both supply and exhaust systems. One item you must consider, though, is the method of finishing the EDGES against which the air is forced. Figure 22 shows how these edges should be streamlined.

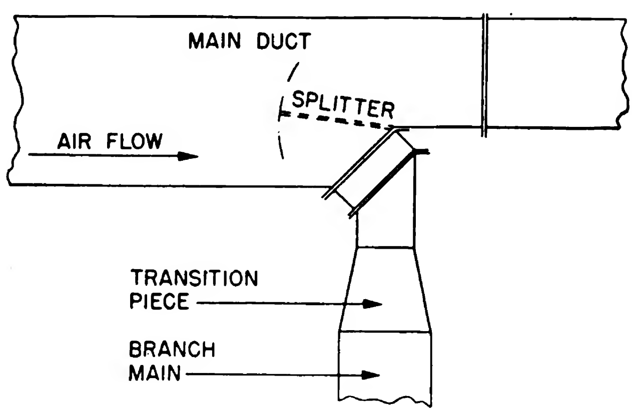


Figure 20.—90° take-off from rectangular duct.

The ventilation systems of older ships may have ROUND-TEE take-offs. Non-watertight round tees are riveted and soldered. The chief problem in making a tee of this type is the layout. Principles of layout for such jobs are covered in chapter 4.

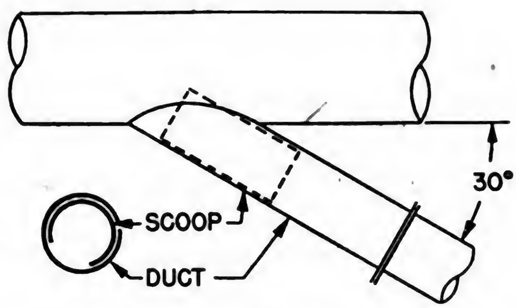


Figure 21.—30° branch take-off with scoop.

THE CHANGE-OVER

The duct fittings used to connect pipes of different sizes and shapes are referred to as being TRANSITION PIECES—that is, CHANGE pieces. They may be almost any shape or size. Their patterns require TRIANGULATION DEVELOPMENTS. That's ex-

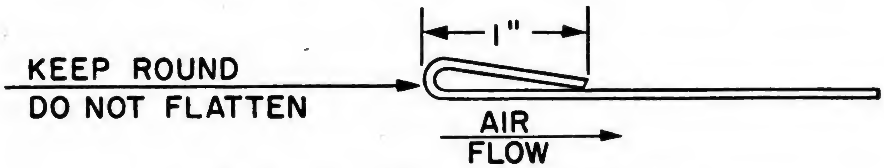


Figure 22.—Keep the edges rounded.

plained in your *Use of Blueprints* training course. True CONICAL shapes may be developed by the radial method.

Here's a point to remember—when you're laying out a replacement for a transition piece you'll usually be able to use the old piece as a pattern if you straighten it out carefully.

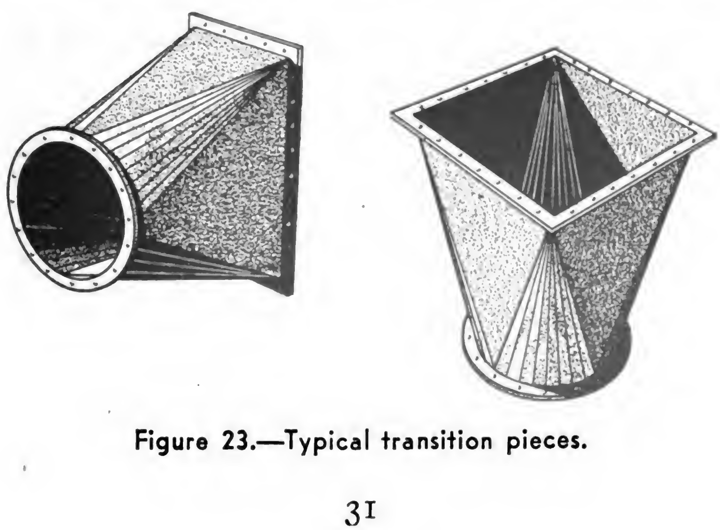


Figure 23.—Typical transition pieces.

VENTURI TUBES AND ARMOR GRATINGS

Ducts passing through armored decks require, as already stated, special installations. Watertight ducts 5 inches or less

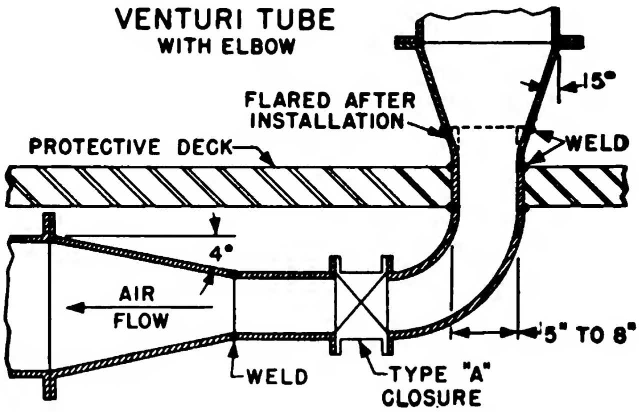


Figure 24.—Venturi tube in armored deck.

in diameter pass through ROUND holes in the armored deck and are welded to the deck. Ducts more than 5 inches in diameter are connected to VENTURI TUBES with flanges, providing the hole for such a tube does not exceed 8 inches in diameter. Figure 24 illustrates an elbow type venturi tube. These sperial jobs must be done very carefully to insure tight connections.

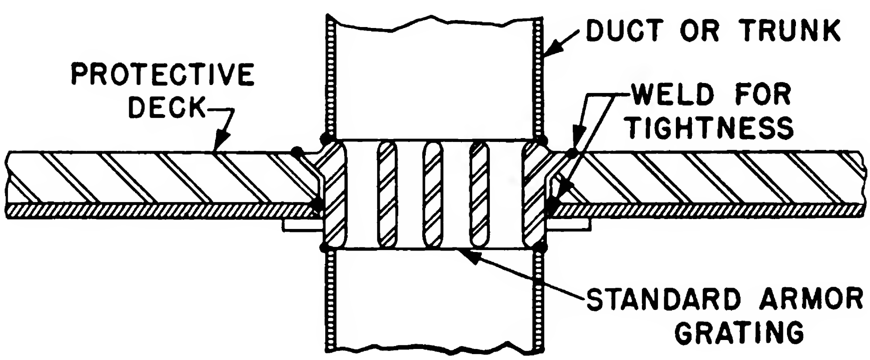


Figure 25.—Use of armored gratings.

Larger ducts require the use of special ARMOR GRATINGS, which are installed as shown in figure 25. You might be called upon to remove or install one of these fittings.

TYPES OF SPACE TERMINALS

Living space supply terminals are ordinarily installed in a vertical position. The open end of the terminal is usually located between 9 and 12 inches from the deck in bunkrooms.

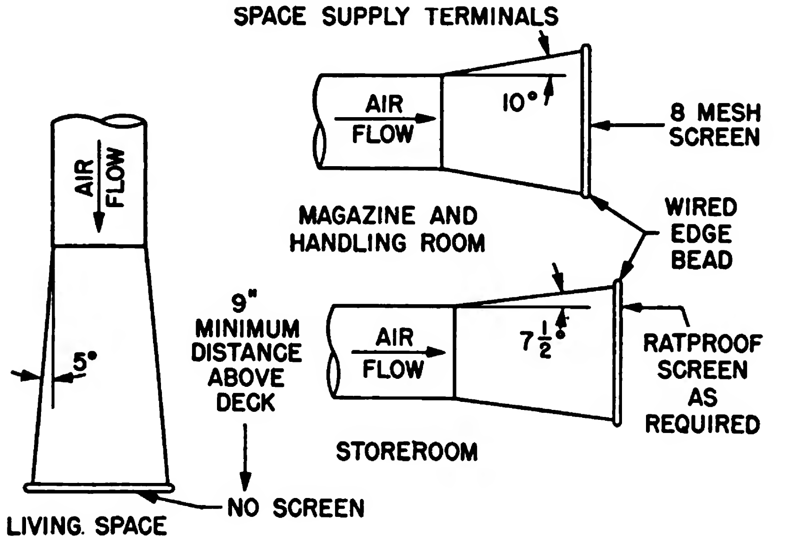


Figure 26.—Standard space supply terminals.

The cone-shaped outlet is designed to lessen the velocity of the air that is discharged into the space.

Supply terminals for magazines, handling rooms, and storerooms are located in a horizontal position near the overhead. They are designed as shown in figure 26. Notice that all the

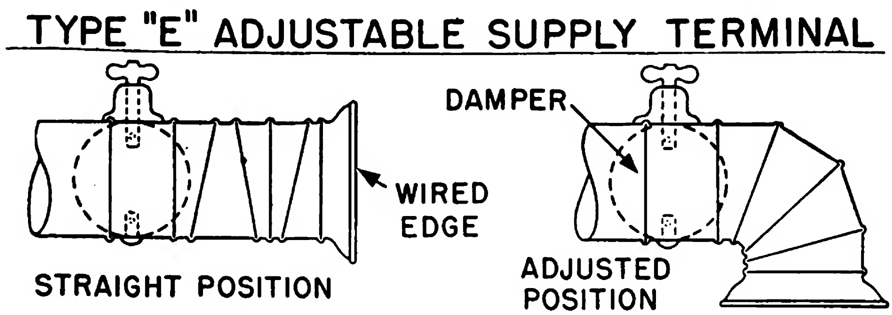


Figure 27.—Adjustable Type E supply terminal.

terminals shown in that figure have wired edges or beads around the opening.

Adjustable supply terminals, Navy Type *E*, are used in such spaces as engine and machinery rooms, radio and sound

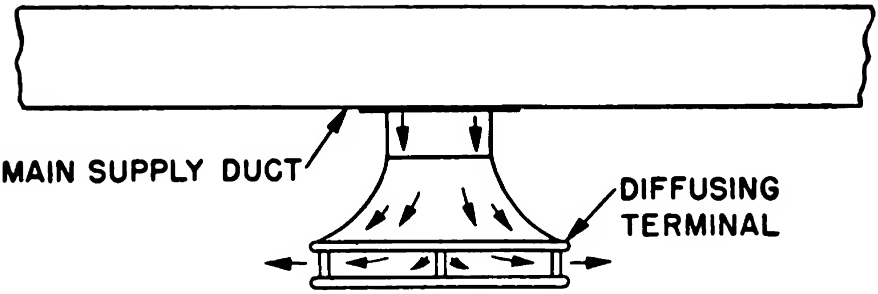


Figure 28.—Diffusing terminal in main duct.

rooms, workshops, laundries and turrets. Adjustable, gored SLIP SECTIONS provide the means of adjustment. Note the DAMPER in the Type *E* terminal shown in figure 27.

Navy standard DIFFUSING TERMINALS are used in offices, staterooms, wardrooms, mess rooms, and in spaces which have air-conditioning (cooled air). A standard diffusing terminal is installed in a main duct as shown in figure 28.

EXHAUST TERMINALS are usually of the bell-mouthed type (figure 29). Damaged terminals of this type should be repaired if possible. You'll have trouble making a new one because the belled end is usually spun to shape.

HAND HOLES AND PLATES

Hand holes are placed in ducts to provde an easy means of inspection and to facilitate assembly and cleaning. A hand hole is ordinarily round and is closed with a cover plate. A collar is fitted to the opening in the duct and flush riveted into place. The cover plate is sealed with a suitable gasket and secured to the collar with short machine screws that fit into holes tapped into the collar. The screw tips should be

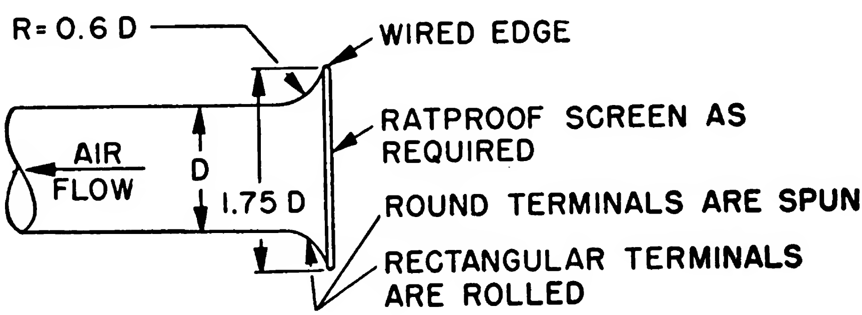


Figure 29.—Exhaust terminal.

flush with the inside wall of the duct to prevent interference with air flow.

All cover plate screws should be kept TIGHT and IN PLACE at all times. You're inviting trouble when you leave a plate secured by only two or three screws.

INSULATION OF VENTILATION DUCTS

Insulation of ducts is AVOIDED whenever possible as the addition of insulation material takes up valuable space and headroom, and makes maintenance and repair more difficult and may be a fire hazard. However, some supply ducts that pass through hot spaces must be insulated. Ventilation HEATERS are insulated—not so much to keep in the heat as to protect personnel from burns.

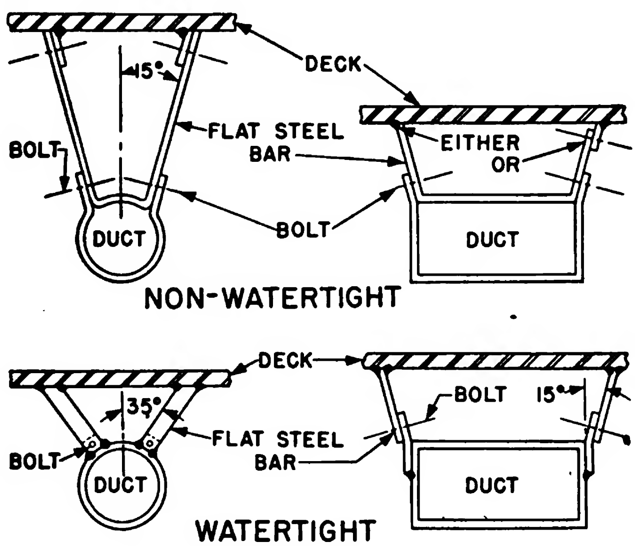


Figure 30.—Duct hangers and brackets.

At the present time the principal material used for insulation is FIBROUS GLASS. This material is light, fireproof, and vermin proof. Some workmen believe this material causes silicosis but this theory is UNTRUE. It's true that the small fibres may stick into and irritate your skin, but a good scrubbing with soap and water takes care of that.

DUCT HANGARS AND BRACKETS

Ventilation duct sections and fittings are supported by hangers, brackets and braces. These are designed to hold the

line securely in place and to minimize vibration. Supports for ventilation lines are made so that fittings and sections of ducts may be easily disconnected for maintenance, repair, and replacement.

A typical assortment of hangers and brackets is shown in figure 30. These are made of flat steel bar stock. Some ducts and terminals may require heavier supports made of angle stock.

CARE AND CLEANING OF DUCTS

Damaged ducts should be repaired AT ONCE. Dented places may be bumped smooth with a dolly and mallet. Cracks and holes should be patched as soon as they appear. Keep in mind that the interior of the duct must be keept smooth and that the cross-sectional area of the duct must be maintained.

Dirty ducts are a definite FIRE HAZARD. Do not allow dust and grease to accumulate in the system. Duct fires are exceedingly dangerous because they spread rapidly from one compartment to another.

Dirty ventilation ducts and fittings also decrease the efficiency of the system by blocking the flow of the air and causing an increase in frictional resistance.

A cleaning CHECK LIST should be followed for each individual supply and exhaust system. The following should be considered minimum requirements—

Ducts	Every six months
Vaneaxial fans	Every six months
Impellers (centrifugal)	Every six months
Duct heaters	Weekly
All screens	Weekly
Cooling coils	Weekly
Grease filters	Twice a week
Laundry exhaust screens	Daily
Lint box	Daily (at least)

Under no conditions should you—or anyone else—use ducts and terminals as storage spaces or secret hideaways for personal possessions.

You must keep all ventilation ducts and fittings DRY as well as clean and clear. Special drains are provided for ducts and fittings that might accumulate water. A rusted duct means lowered efficiency of the system and earlier replacement of the

rusted section. Replacements mean more work—and lowered efficiency, if it goes too far, will put you right back where those old salts of 1779 were. You don't want that!

CHAPTER 4

SHEET METAL PATTERN DEVELOPMENT

ROLLING YOUR OWN

"Rolling your own" is just another way of saying "develop your own sheet metal patterns". The layout of boxes, pans, trays, buckets, small tanks, funnels, pipe joints, and ventilation ducts and fittings is part of your job.

Parts and pieces which have straight lines and flat surfaces are easily laid out by measurement. CYLINDRICAL shapes are simple to "roll out" by the PARALLEL DEVELOPMENT method. Conical shapes are developed by the RADIAL method, while you ordinarily lay out odd and unusual shapes by TRIANGULATION.

All of the above methods are illustrated and explained in the training course, *Use of Blueprints.* This chapter gives you the development of specific layout problems you may encounter. Most of these problems are concerned with ventilation fittings and ducts, but the same principles apply to laying out similar objects and shapes.

LEARN BY PRACTICE

The best way to learn pattern development is to practice with a great variety of patterns. Make your practice developments on heavy brown wrapping paper.

Mount the paper on a large drawing board or table top. Use a T-square to lay out horizontal lines. Use triangles with

the T-square to draw vertical and slant lines. For drawing arcs and circles you'll need both large and small compasses. They'll serve for transferring measurements, too, along with several pairs of large and small dividers. Other handy accessories include a straight edge, a circumference rule, trammel points, and a combination square set.

When you make a practice layout, measure and mark each line as accurately as possible. When the layout is finished, add the necessary allowances for seams and joints. Then cut

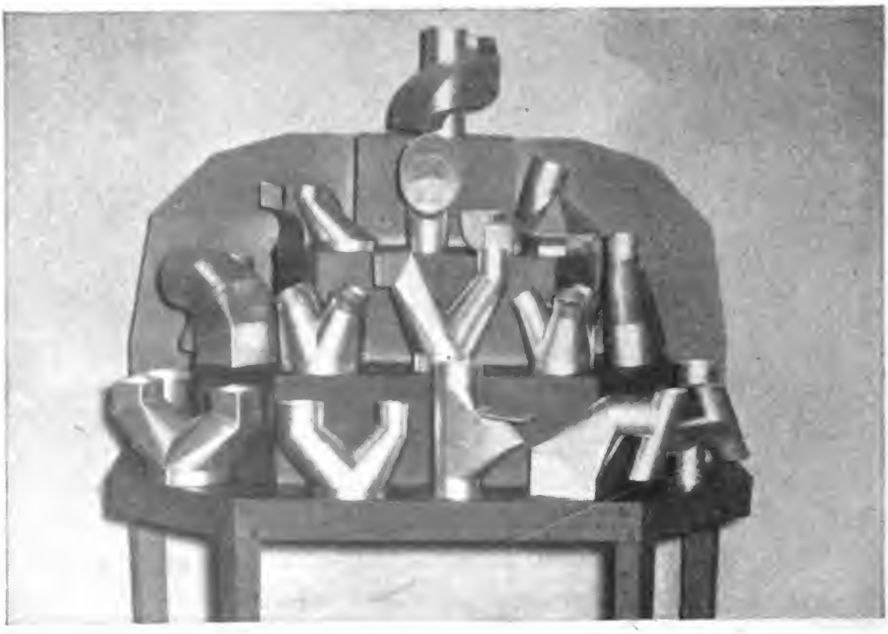


Figure 31.—Ventilation fittings made by a class of rated Metalsmiths and shipfitters of a ship repair training unit.

out your paper patterns, form them up, and stick them together with cellulose tape or masking tape. You'll get a thrill when you've completed a complicated layout, formed it up, and discovered it's exactly right.

MAKING A PARALLEL DEVELOPMENT

The first step in making a parallel development (figure 32), is to draw a full size orthographic FRONT view of the cylinder. Note that the front view is selected to show the PROFILE of the cylinder. Place this view in the lower left-hand corner of your layout paper.

The next step is to draw the TOP view, or half of the top

view. Half is all that's required for this problem. Lines on both views must be laid out accurately. If angles and circles are not EXACTLY right, your pattern cannot be accurately developed.

Next, DIVIDE the half-circle of the top view into a convenient number of equal parts. For this development the half-circle is divided into SIX equal parts, so that TWELVE of these equal parts represent the circumference of the cylinder. These twelve parts or SEGMENTS are stepped off on the BASE LINE, as shown in figure 32.

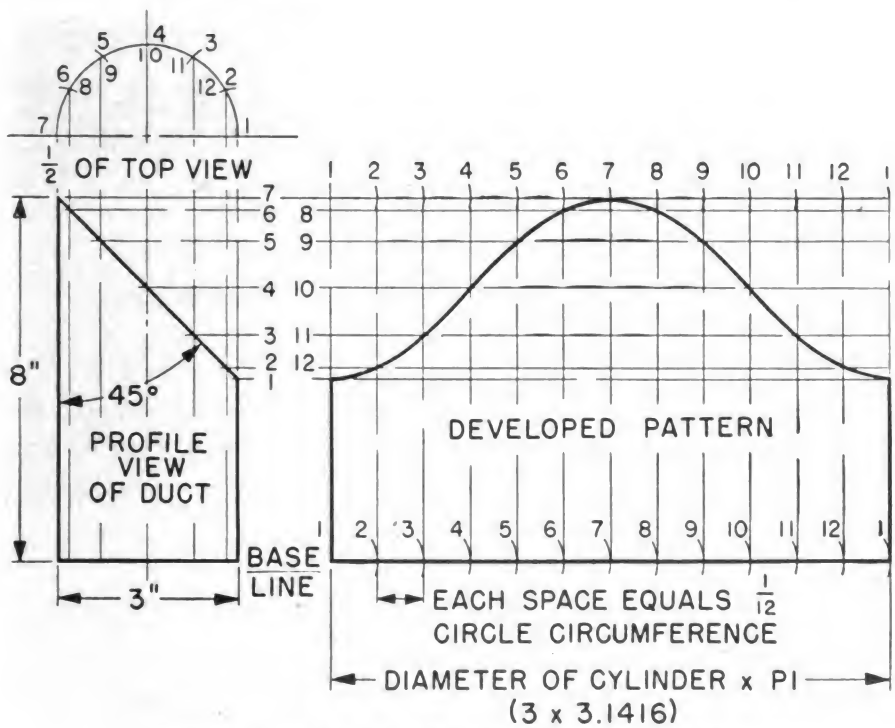


Figure 32.—Parallel development of a cylinder.

The base line is made as a continuation of the bottom line of the front view. Its length must be exactly EQUAL to the circumference of the circle. Vertical ELEMENT lines are then dropped from the divisions of the half-circle of the top view to cut the slant line of the front view.

Now for the HORIZONTAL lines. From each POINT OF INTERSECTION on the front view, run a horizontal line to the right to intersect the vertical element lines of the pattern. These horizontal lines must be PARALLEL to the base line. Number all of the lines.

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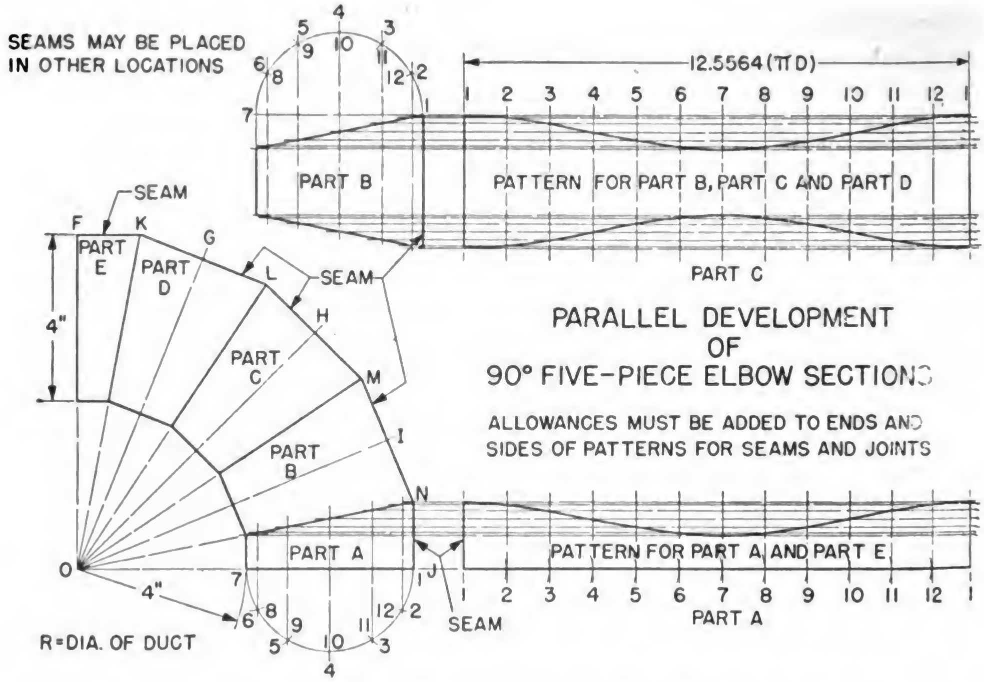


Figure 33.—Parallel development of a 90° five-piece elbow.

Then place a DOT at the intersection of horizontal line *1* with vertical line *1*. Place another dot at the intersection of horizontal line *2* with vertical line *2*. Continue until all the dots are located. Then fair a line through all the dots to establish the CURVED OUTLINE of development.

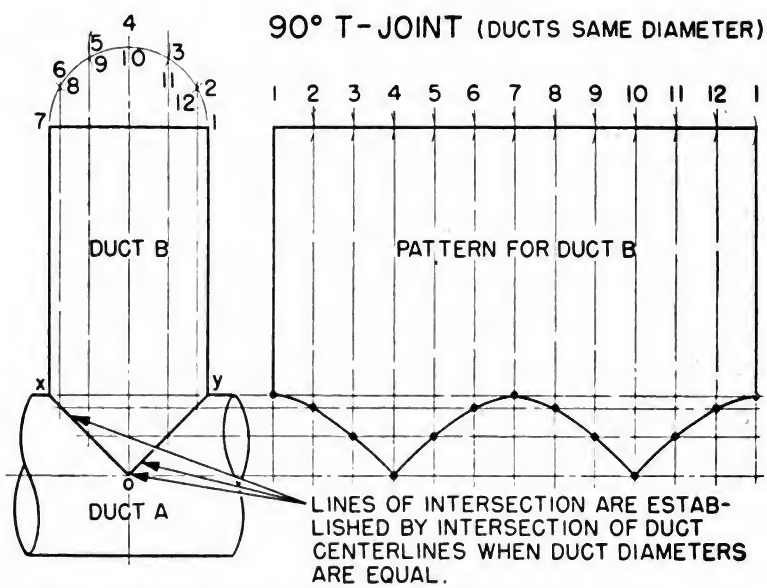


Figure 34.—T-joint for air ducts of the same diameter.

Any cylindrical pipe, duct, tank, or other object may be developed by this parallel development method. If a development is to be used as a pattern, material allowances must be ADDED for the necessary seams, joints, hems, or wired edges.

ROUND ELBOW DEVELOPMENT

The development of the 4-inch, 90°, 5-piece, round elbow in figure 33 is another example of the parallel or roll-out method. This development is made in exactly the same manner as that shown in figure 32. The new phase of this job is the METHOD OF DRAWING the orthographic front view of the elbow.

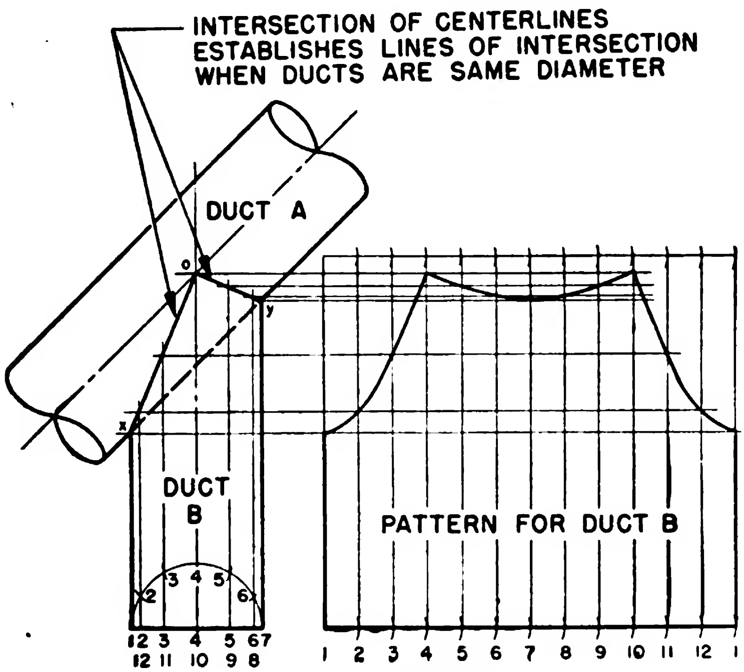


Figure 35.—45° joint of ducts having the same diameter.

Here's how to draw this front view. Locate point O in the lower, left-hand corner of the sheet of layout paper. Then construct lines OJ and OF which must be at RIGHT ANGLES to each other. Set a compass at 4 inches and swing an arc which intersects both OJ and OF. Reset the compass to 8 inches and swing an arc which intersects both OJ and OF.

Next, divide angle FOJ into FOUR equal angles by constructing the lines OG, OH, and OI. Then bisect—cut in half—

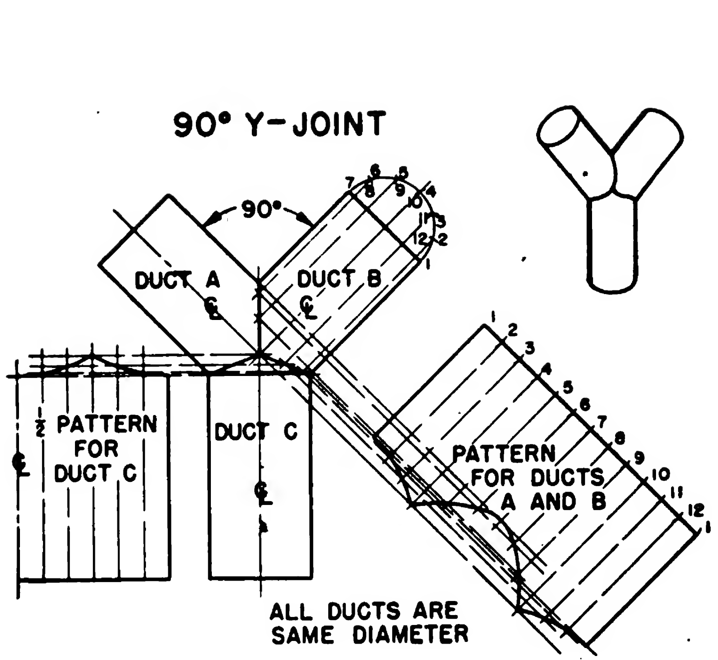


Figure 36.—Developing a 90° Y-joint.

each of the four angles, *FOG, GOH, HOI,* and *IOJ.* This establishes lines *KO, LO, MO,* and *NO,* which are the dividing lines or joints between the pieces of the elbow. Remember this rule—to lay out any elbow, divide the angle of the elbow into ONE LESS equal parts than the number of pieces of the elbow.

Develop each part or piece of the elbow by the parallel method, because each piece is cylindrical. Notice that developments have been made only for Part *A* and Part *C.* Actually

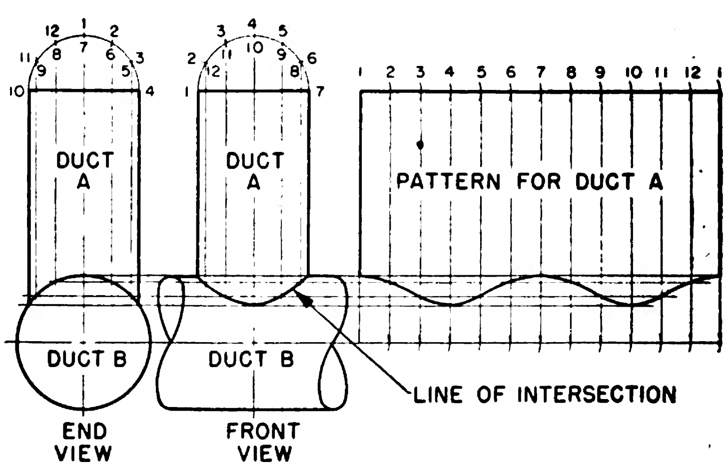
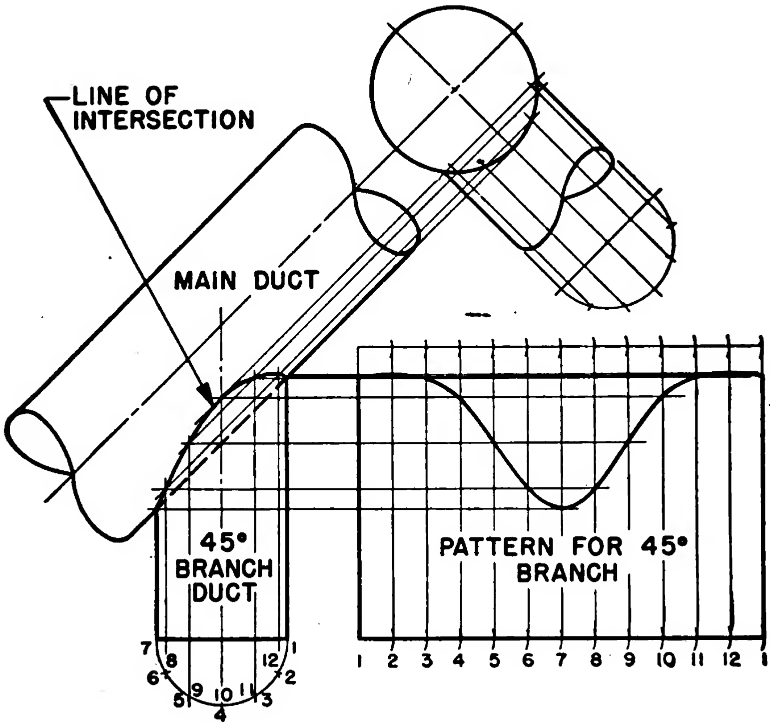


Figure 37.—T-joint of ducts of different diameters.

only the development for Part *A* is required because Part *A* is the SAME as Part *E*, and Part *A* is equal to ONE-HALF of Parts *B*, *C*, and *D*.

Remember to add the necessary allowances to the pattern for seams and joints. Make sure that the circumference is correct by laying it out MATHEMATICALLY. Multiply pi (3.1416) times the diameter to secure the exact stretch-out length. And



45° BRANCH
FOR DUCTS OF DIFFERENT DIAMETERS

Figure 38.—Development of a 45° branch of a larger duct.

remember that the THROAT radius—inside diameter—of any elbow is usually made EQUAL TO the DIAMETER of the pipe or duct.

INTERSECTING CYLINDERS

Developments for intersecting cylinders of the SAME DIAMETER are easily made because their LINES OF INTERSECTION are readily found. On the drawing of air ducts in figure 34, one line of intersection is marked *OX* and the other line of intersection is marked *OY*. Note that the point *O* is established by the intersection of the centerlines of the two cylinders.

After the lines of intersection are located, the development of Duct *B* is made by the parallel method. The same method may be used to develop a pattern to show the size and shape of the opening in Duct *A*.

Ducts or pipes that intersect at ANY angle may be developed by the method shown in figure 35, which is essentially the same used to develop the *T*-joint in figure 34. Remember, though, this method cannot be used unless the intersecting ducts are of the SAME diameter.

The *Y*-joint (figure 36) is formed by the intersection of THREE ducts of the same diameter. The lines of intersection are established by the intersection of all three duct centerlines. Developments for all three ducts are made by the parallel method.

When a SMALL cylindrical duct intersects a LARGER cylindrical duct, your only new problem is establishing the LINE OF INTERSECTION. Look at figure 37.

Here's how the line of intersection of the two ducts is found. Draw full size front and end views as shown. Then draw HALF-CIRCLES at the top of Duct *A* in each view. Divide the half-circles into the same number of equal parts—6 parts in this case.

Now drop ELEMENT lines on both views to intersect Duct *B*. Then run HORIZONTAL lines from each intersection in the END view of an element line and the circle. Intersections of these horizontal lines with the vertical element lines of the FRONT view are used to locate the line of intersection.

After the line of intersection is established, Ducts *A* and *B* are developed by the parallel method. Only the development of Duct *A* is shown in figure 37.

When ROUND ducts of different diameters intersect at an angle other than 90°, the line of intersection is found by the same method used for the *T*-joint. One of these developments, made for a 45° branch joint, is shown in figure 38. The accuracy of a development of this type depends largely on exact measurements and careful line constructions.

OFF-CENTER INTERSECTIONS

Cylinders of UNLIKE diameters intersecting OFF-CENTER require special treatment because the developed outlines are not uniform. Half-patterns are not used—the WHOLE pattern must be developed—unless the intersection is at right angles.

To make this development, as shown in figure 39, start by drawing the front view and the end view FULL-SIZE. Then construct element lines for the small cylinder on both views. Locate the line of intersection on the front view, as shown. (The dash line represents the back line of intersection.)

Next draw the STRETCH-OUT for the large cylinder. Lay off (from the end view) at the right edge of the stretch-out, the

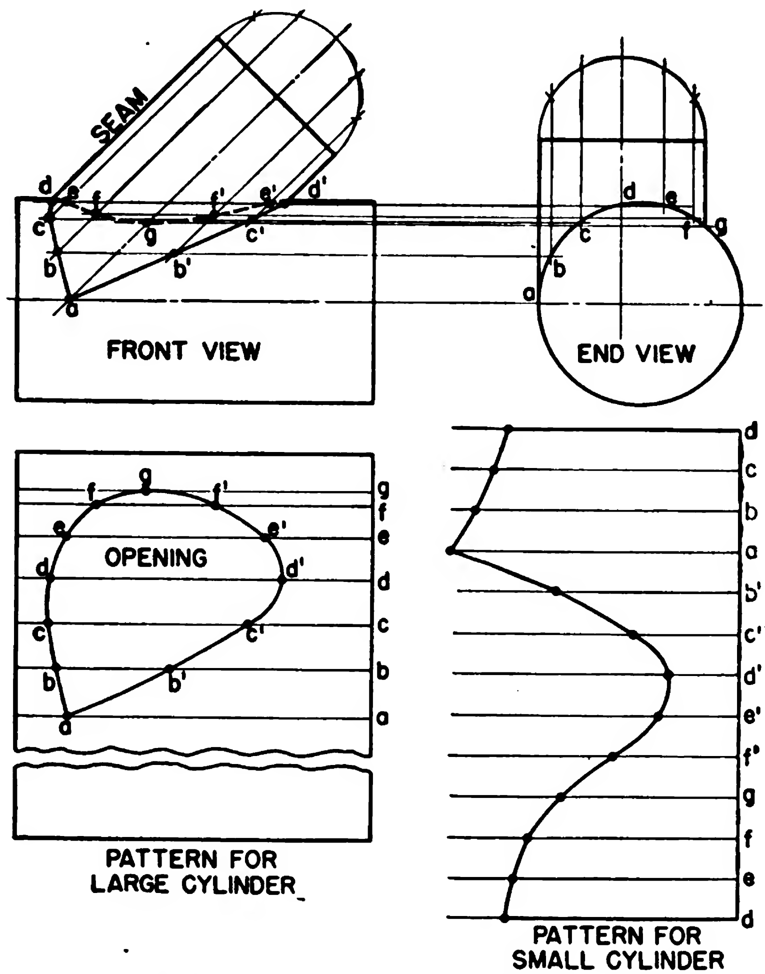


Figure 39.—Off-center intersection of cylinders of unlike diameters.

distances *gf, fe, ed, dc, cb,* and *ba* on the stretch-out for the large cylinder. Drop lines from points on the line of intersection—FRONT view—vertically to locate these points on the STRETCH-OUT. Fair in the line forming the outline of the opening.

Now develop the pattern for the small cylinder by parallel development. In this case do so by transferring measure-

ments from the FRONT VIEW and applying them to the base line *dd* and the element lines of the small cylinder stretch-out.

INTERSECTION OF CONE AND CYLINDER

Cone and cylinder intersections are not difficult but they require an accurate and precise layout. Here are the steps in making the layout (see figure 40).

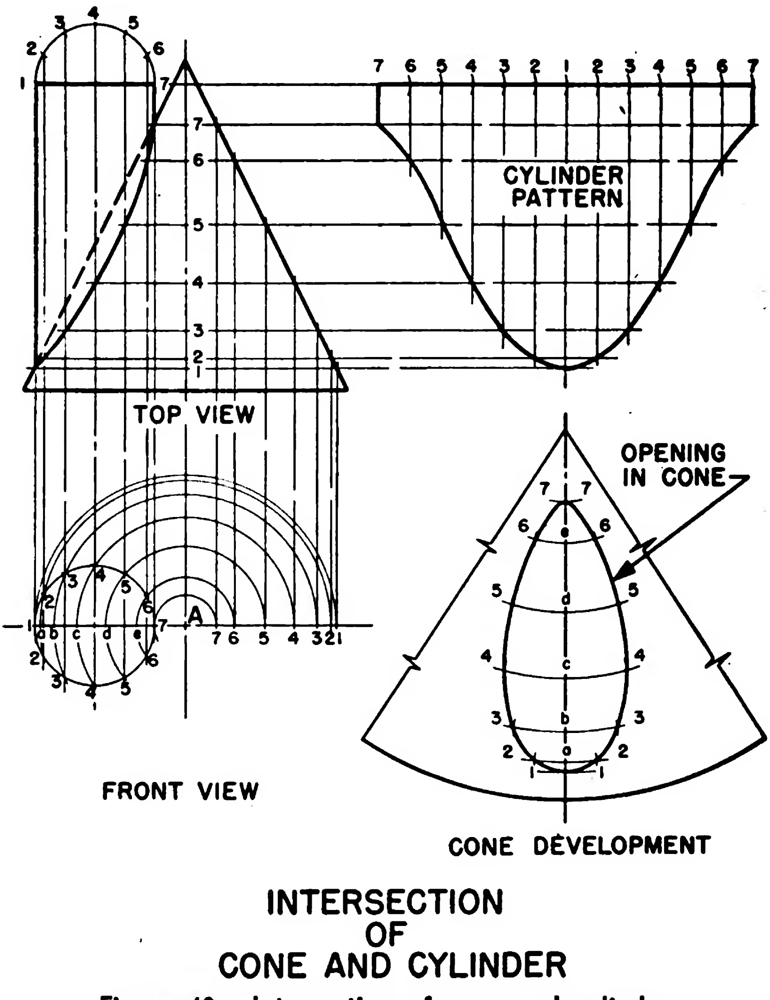


Figure 40.—Intersection of cone and cylinder.

Draw the two orthographic views. Establish element lines on the half-circle of the cylinder in the top view and extend them to the end of the cylinder in the front view.

Use point *A* as a center and swing ARCS through each intersection of a cylinder element line with the end view of the cylinder. These arcs MUST INTERSECT the horizontal center-line of the front view.

From the established points run VERTICAL lines to intersect the right side of the cone—top view. From the points of intersections run HORIZONTAL lines to the left to intersect the original element lines of the cylinder. Intersections of corresponding lines locate POINTS of intersection through which a LINE of intersection can be faired.

Then develop the cylinder by conventional parallel development, and the cone cut-out as shown in figure 40. Remember —the length of line *5d5* (cone development)—is equal to the length of ARC *5d5* of the circle of the FRONT view.

TRANSITION PIECES

Often it is necessary to change the shape or area of a duct or pipe. This change is accomplished by means of TRANSITION PIECES and other special fittings.

Unfortunately, on a transition piece, most of the lines of the orthographic views are NOT shown in their TRUE length. That's because the lines of the orthographic views slant away —back from—the surface shown by the view. And that's why you have to find the TRUE LENGTH of some of the lines.

The true length of lines on transition pieces is found by TRIANGULATION. In this method, the surface of the orthographic front view is cut into a number of triangles. Then the true length of each side of each triangle is determined. This true length is then transferred to the development.

SQUARE-TO-SQUARE

The transition piece in figure 41 is easily developed because the openings have the same shape and are centered, and also because all four sides or surfaces of the piece have the same shape and size.

The top and bottom lines of this piece are the ONLY lines shown in their TRUE length on the front and top views. The slant lines—which are all the same length—are NOT shown in their true length. It is found by drawing the circles shown in the top view of the drawing. From the intersections of these circles with the horizontal centerline, lines are dropped to locate point *E* and point *F*.

After the construction is completed on the front view and the top view, the development is easily and quickly made. Start it from point *O* by swinging arcs which have radii equal

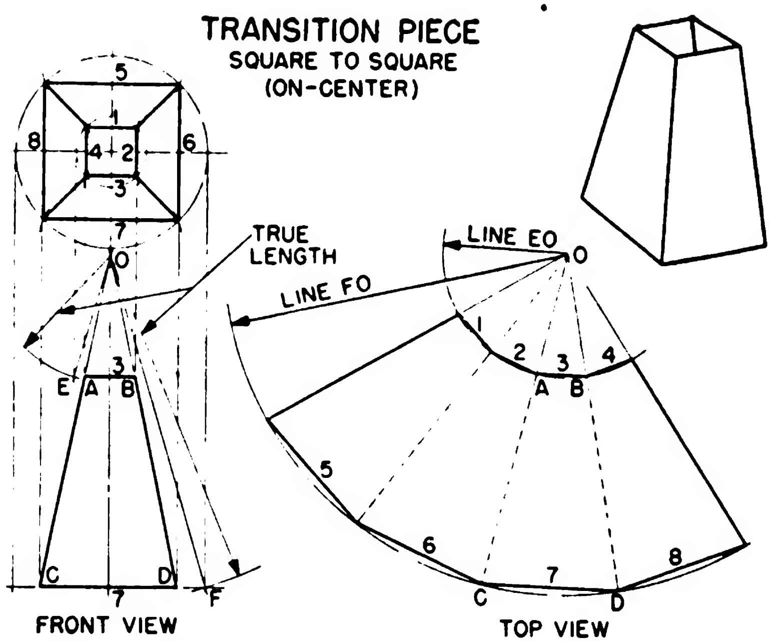


Figure 41.—Square-to-square transition piece.

to lines *EO* and *FO*. Lines *1*, *2*, *3*, and *4* on the development are all equal to line *3* of the front view, which is the same as line *AB*. Lines *5*, *6*, *7*, and *8* of the development are all equal to line *7* of the front view, which is the same as line *CD*.

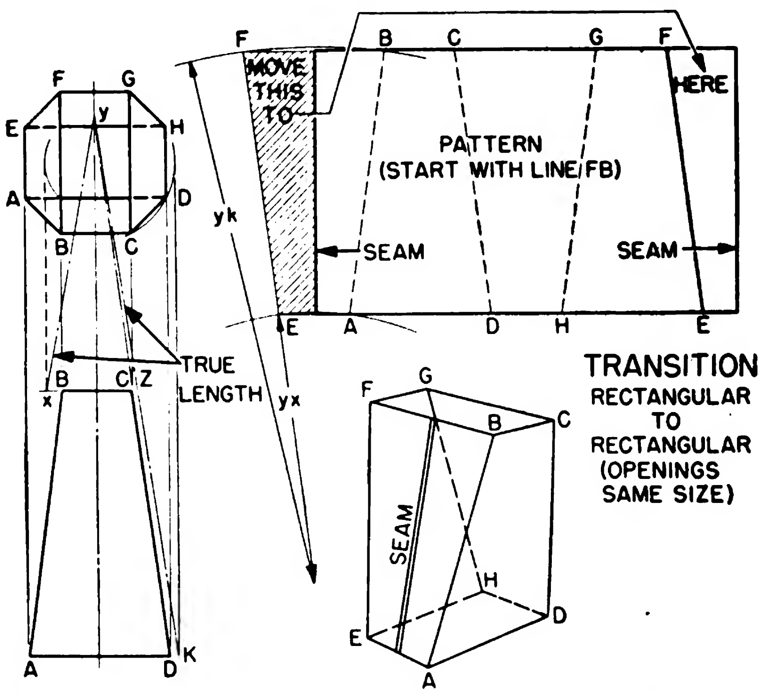


Figure 42.—Rectangular-to-rectangular transition with openings same size but reversed.

ERRATA

The Insert in Metalsmith 1c and Chief, Navy Training Courses, Navpers 10131, 1946 Edition, which appears as facing page 50 should appear as facing page 20.

RECTANGULAR-TO-RECTANGULAR

Transition pieces like the one shown in figure 42 are developed by a method similar to that used for square-to-square

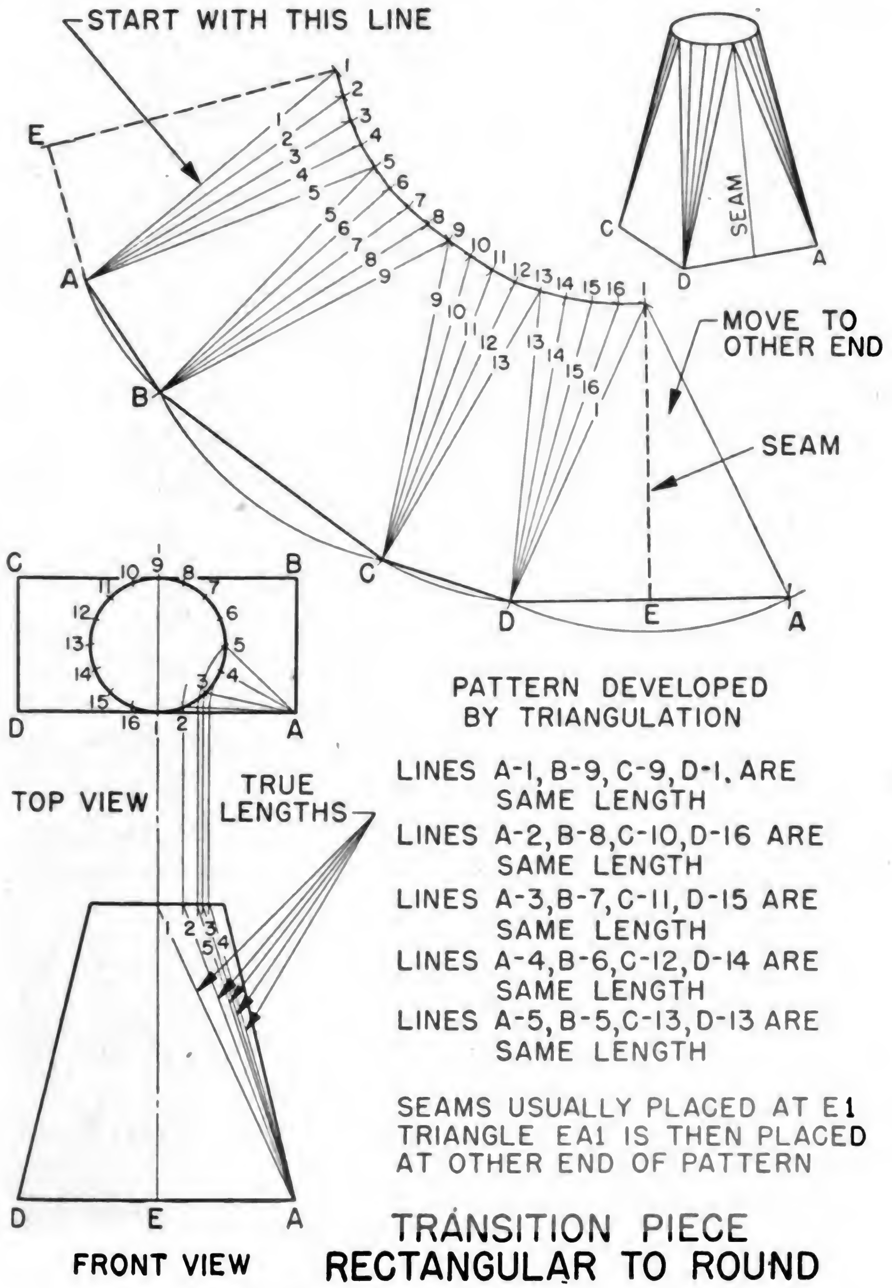


Figure 43.—Rectangular-to-round transition piece.

transitions. This piece has four sides or surfaces that are IDENTICAL. Two of the pieces are reversed—turned end for end—to get the desired shape.

You need make only one side (*FBEA*) of the transition. Then you can transfer measurements to form the other three sides. The seam is usually placed down the middle of one side, rather than in a corner.

ROUND-TO-SQUARE

Development of a round-to-square transition piece is explained and illustrated in the *Use of Blueprints* training course. In the example shown in that book, the transition piece is symmetrical and may be developed by a combination of radial and triangular development.

RECTANGULAR-TO-ROUND

When you've done the round-to-square transition try making the rectangular-to-round job shown in figure 43. It's not difficult and you can make it on your own by referring to the drawing.

OFF-CENTER ROUND-TO-ROUND

Triangulation is used to develop a pattern for a round-to-round transition piece when the circular ends are OFF-CENTER. The method of making this type of development, shown in figure 44, appears complicated but is not difficult when worked out step-by-step.

Draw the orthographic FRONT VIEW first. Then swing in the half-circles at top and bottom. With the front view completed follow these steps—

- Divide the top half-circle into 6 equal parts to establish points *A, B, C, D, and E;*
- Drop vertical lines from these points to intersect the top line of the front view;
- Divide the bottom half-circle into 6 equal parts to establish points *F, G, H, J,* and *K;*
- Run vertical lines upward to intersect the bottom line of the front view;
- Construct the front view TRIANGLES as shown; note that some of the lines are solid and some broken—make your lines the same way.

Now find the TRUE lengths of the sides of the triangles. The short side of each triangle that points DOWNWARD is equal

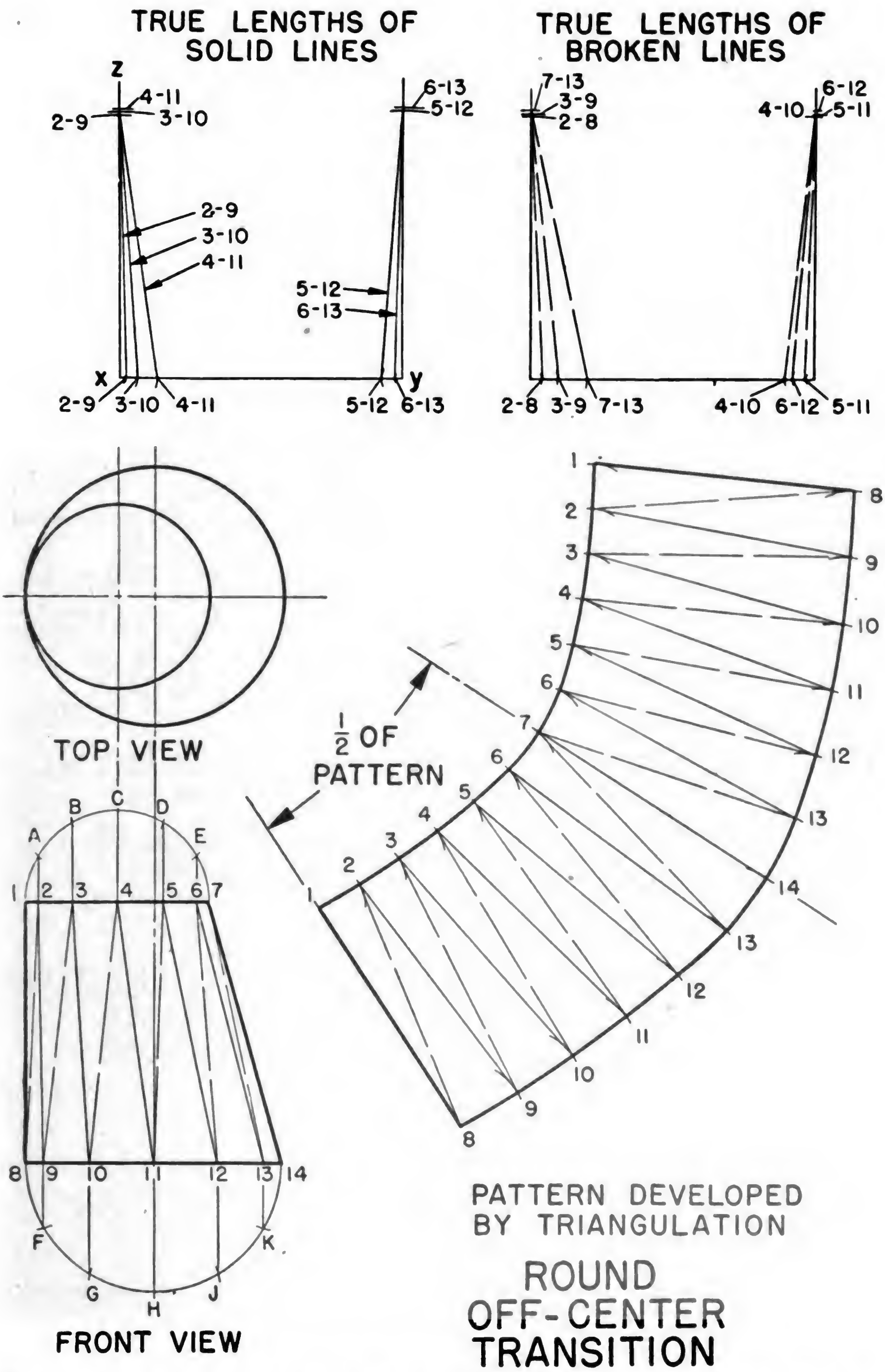


Figure 44.—Development of off-center, round-to-round transition piece.

to ONE-TWELFTH the circumference of the TOP circle. The short side of each triangle pointing UPWARD is equal to one-twelfth of the circumference of the BOTTOM circle. The other two sides of each triangle are not shown in true length and triangulation must be used to determine their true

lengths. Lines *1-8* and *7-14*, however, are shown in their true length on the front view.

Work on the SOLID lines first. (See the top portion of Figure 44.) Set up two right angles to use as bases and work from point *X* and point *Y*. Take line *3-10* as an example. Set a compass to the length of line *3-10* of the FRONT view. Use point *X* as a center and swing an arc across line *XZ*. Then set the compass to equal the DIFFERENCE between

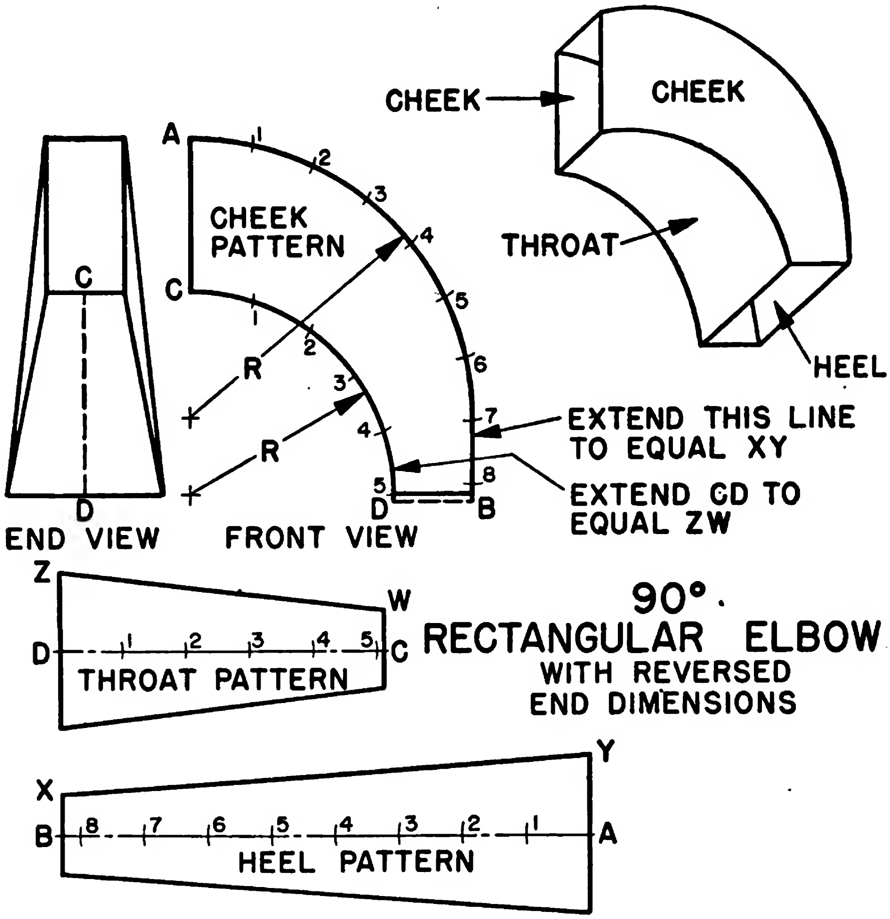
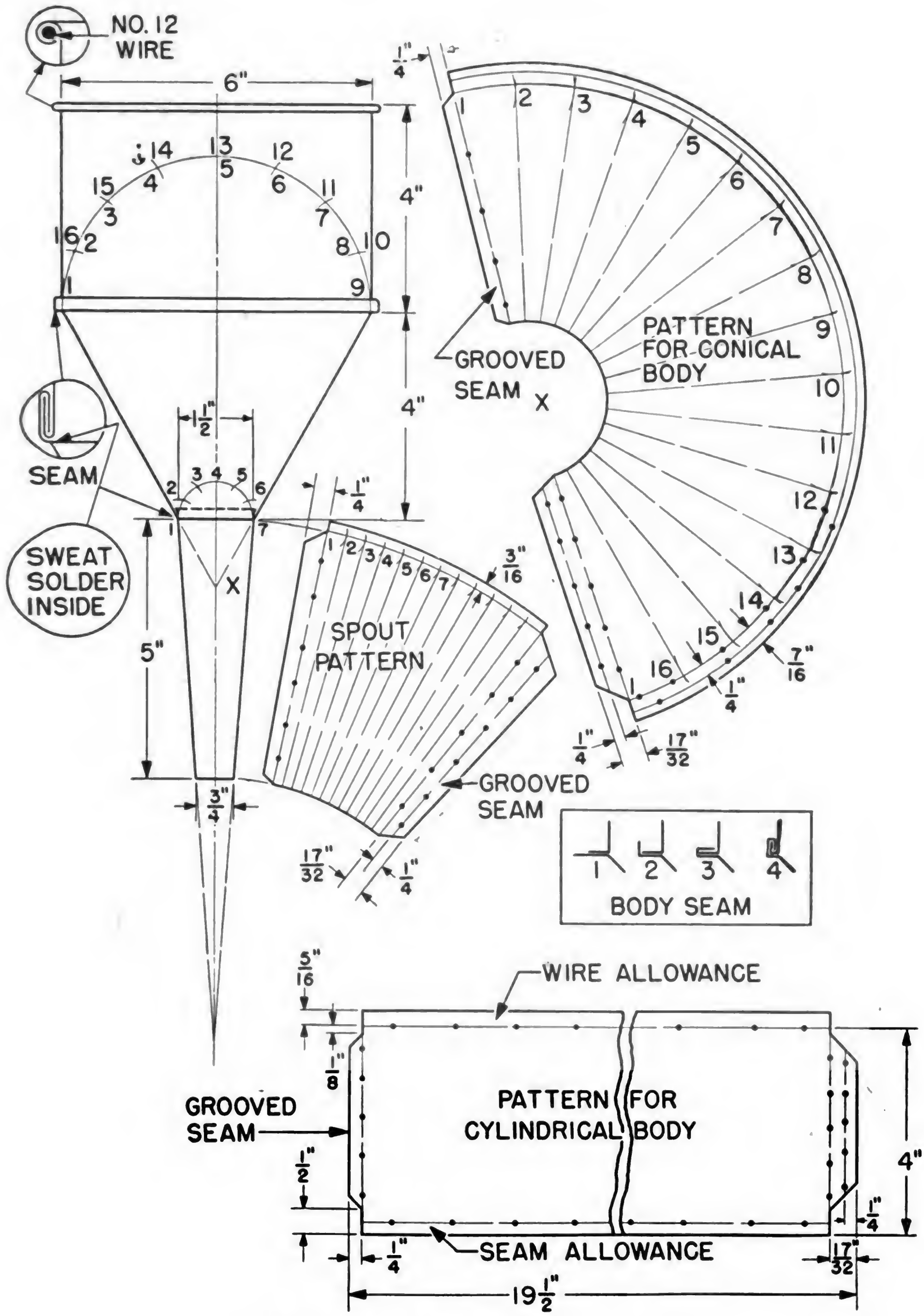


Figure 45.—90° rectangular elbow with reversed openings of the same size.

line *G-10* and line *B-3*. Use *X* as a center and swing the arc to intersect line *XY*. A line connecting the two intersections thus established—*XZ* and *ZY*—is the TRUE LENGTH of line *3-10*. The same method is used to find the true length of each side of each triangle of the front view.

With the true lengths established for all the solid lines and all the broken lines, lay out the development. Start with line



6-INCH FUNNEL
WITH CYLINDRICAL EXTENSION
MAKE OF 24 GAGE GALVANIZED STEEL

Figure 46.—A good six-inch funnel.

1-8 and construct triangle *1-8-2*, (lower right hand portion, figure 44). Then construct triangle *8-2-9*, then *2-9-3*. Continue until you reach line *7-14*. When you reach this line, one-half of the pattern has been developed. That's all you

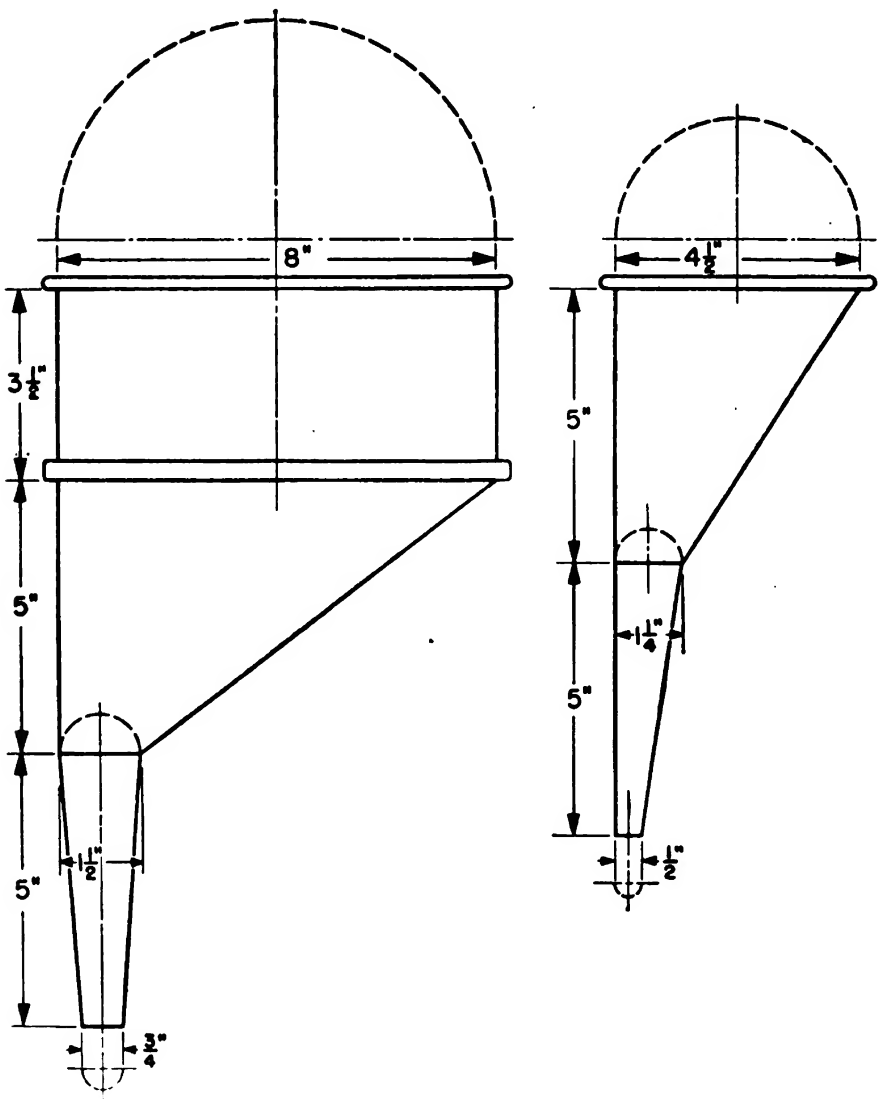


Figure 47.—Develop these jobs to test your ability.

need because the other half is identical. You can develop the second half for practice but it's not necessary.

90° REVERSED-END RECTANGULAR ELBOW

A 90° RECTANGULAR ELBOW with reversed end dimensions is developed in figure 45. To make the layout draw the front

and end views, then measure the length of line *AB* in the front view by the "step-off" method.

Transfer this length to another line labeled *BA*. Draw perpendicular end lines equal to lines *AC* and *BD* of the front view at each end of line *BA*. Draw in line *XY* and its corresponding line on the opposite side of line *BA*. That completes the HEEL. Use the same method to develop the THROAT.

Now extend line *AB* of the CHEEK pattern so that its length is equal to the length of line *BA* of the HEEL pattern. Line *CD* of the CHEEK pattern should be extended to equal the length of line *ZW* of the THROAT pattern. Add seam and joint allowances if the piece is to be fabricated.

LAYOUT FOR A SIX-INCH FUNNEL

When a good FUNNEL is needed, you can make up one like that shown in figure 46. You can form a conical funnel of any size or shape if you draw the front view (orthographic) and make the development as shown.

The TOP piece (cylindrical body) is developed by the PARALLEL method. The CENTER piece (conical body) and the SPOUT are developed by the RADIAL method. All pieces must be developed with extreme care and accuracy or they will not fit when assembled.

TEST YOURSELF

Two OFF-SET FUNNELS are shown in figure 47. Their development is left to you as a challenge to your ability as a pattern expert. Use figure 44 as a reference.

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CHAPTER 5

OXYACETYLENE WELDING AND BRAZING

WELDING KNOW-HOW

To qualify as a Metalsmith 2c you had to know simple oxyacetylene welding, brazing, and silver-soldering. As a Metalsmith 1c or Chief you're expected to handle ANY welding or brazing job that comes up, with the exception of welding pressure vessels.

Advanced work in welding—doing the tough and unusual jobs—is largely a matter of basic and fundamental skills, which you have, and additional welding KNOW-HOW. You've learned the SAFE handling and assembly of welding equipment, flame adjustment techniques, and torch manipulation. You're also able to obtain proper penetration, fusion, strength, and appearance when you weld with the oxyacetylene torch. So all that's needed is that additional know-how.

Some welding know-how comes only with PRACTICE, but much can be developed by reading this chapter and the texts published by leading manufacturers of welding equipment. The material included in this chapter is intended to help you handle the unusual and complicated welding and brazing jobs —the kind that are always popping up when you least expect them.

When such a job comes your way, the first thing to do is

ask yourself some of the questions that fellow in Figure 48 is putting to himself.

Find the answer to EACH question before you light the torch. If you don't know the answer and can't find it here, look it up elsewhere or ask someone who does know. Remember, however—a Metalsmith 1c or Chief is supposed to KNOW THE ANSWERS. Your men will be coming to you for information and advice—be prepared!

You can't know by heart all the FLAME ADJUSTMENT and PREHEATING TEMPERATURES for the chief base metals and alloys, though you'll soon find you can recall most without looking them up. Until that time, and for use whenever you're in doubt, here's a tabulation for ready reference.

Figure 48.—Ask yourself these questions.

FLAME ADJUSTMENT AND PREHEATING FOR OXYACETYLENE FUSION WELDING OF FERROUS METALS

Base Metal	Flame Adjustment	Preheating
Iron, black soft	Neutral	None.
Iron, cast alloys ...	Neutral	500-1000° F.

Iron, cast gray	Neutral	700-800° F.
Iron, wrought	Neutral	None.
Steel, cast alloys ..	Slightly carburizing.	In some cases.
Steel, cast carbon ..	Neutral	200° F.
Steel, corrosion-resisting	Neutral to slightly carburizing	None.
Steel, low-alloy, high-tensile	Neutral to slightly carburizing	For some alloys.
Steel, high-carbon .	Carburizing	300-500° F.
Steel, low-carbon ..	Neutral to slightly carburizing	None.
Steel, medium-carbon	Neutral to slightly carburizing	300-500° F.

FLAME ADJUSTMENT AND PREHEATING FOR OXYACETYLENE BRAZING OF FERROUS METALS

Base Metal	Flame Adjustment	Preheating
Iron, black soft....	Slightly oxidizing...	None.
Iron, cast alloy....	Slightly oxidizing...	Local to 500°F.
Iron, cast gray....	Slightly oxidizing...	Local to 500°F.
Iron, wrought.....	Slightly oxidizing...	None.
Steel, cast carbon..	Slightly oxidizing...	For some alloys.
Steel, cast carbon..	Slightly oxidizing...	Local to 500°F.
Steel, high-carbon..	Slightly oxidizing...	300-500° F.
Steel, low-carbon...	Slightly oxidizing...	None.
Steel, medium-carbon	Slightly oxidizing...	200-400° F.
Steel, tool.........	Slightly oxidizing...	Up to 1000° F.

FLAME ADJUSTMENT AND PREHEATING FOR OXYACETYLENE FUSION WELDING OF NON-FERROUS METALS

Base Metal	Flame Adjustment	Preheating
Al–17, Al–24 (welding not recommended for these alloys)		
Al–4, Al–52.......	Neutral	500-800° F.

Al–51, Al–53	Neutral	Up to 400° F.
Al–2 (pure Al.), Al–3	Neutral	500-800° F.
Brass, naval; Muntz Metal; Tobin Bronze; mang. br.	Oxidizing	200-300° F.
Brass, Yellow; brass, spring	Oxidizing	200-300° F.
Bronze, aluminum	Slightly carburizing	200-300° F.
Bronze, commercial; Brass, Low	Oxidizing	200-300° F.
Bronze, phosphor	Neutral	300-500° F.
Copper, deoxidized	Neutral	500-800° F.
Inconel; Monel; Nickel	Carburizing	200-300° F.
Lead	Neutral to carburizing	None.
Magnesium alloys	Slightly carburizing	500-600° F.
White metal (die cast)	Carburizing	None.

FLAME ADJUSTMENT AND PREHEATING FOR OXYACETYLENE BRAZING OF NON-FERROUS METALS

Base Metal	Flame Adjustment	Preheating
Bronze, commercial and low brass	Slightly oxidizing	200-300° F.
Bronze, phosphor	Slightly oxidizing	200-300° F.
Copper, deoxidized	Slightly oxidizing	400-600° F.
Monel; Inconel	Slightly oxidizing	200-300° F.
Nickel	Carburizing	200-300° F.

POSTHEATING

Many welding, brazing and silver-soldering operations require POSTHEATING—heating the joined parts AFTER they are joined. As a rule, postheating is required when pieces of DIFFERENT sizes and thicknesses are welded or brazed together.

The purpose of postheating is to EQUALIZE THE RATE OF

COOLING—to keep the rate of cooling UNIFORM throughout the heat-affected areas of both joined pieces. Because small thin masses cool more rapidly than large thick masses, most of the postheating is done on the SMALLER section. For example, when you braze a flange to a pipe, the pipe should be postheated because it cools faster than the heavier flange.

ROD AND FLUX SPECIFICATIONS

To do any welding job correctly you must know the specifications of your RODS and FLUXES, what these "specs" mean, and how properly to use them in requisitioning.

NAVY DEPARTMENT SPECIFICATION NUMBERS—symbols—are designated for most of the FLUXES and WELDING RODS you'll use. In addition to the specification number, many items are further classified by class, grade, and type. Further information about size and composition is sometimes given.

FEDERAL STANDARD STOCK CATALOG ITEM NUMBERS are assigned to standard items by the federal government. An example of one of these numbers is 46-R-480 which indicates an Al-2 aluminum welding rod with a diameter of 3/32 inch. The equivalent N.D. Spec. No. is 46R7, Class A, size 3/32 inch.

THE NAVY DEPARTMENT ACCEPTABLE LIST is a publication which lists items made by various manufacturers which meet the specifications and standards established by the Navy Department.

COMMERCIAL TRADE NAMES or brand names are also used to specify items of material but should not be used alone. When you specify material to be ordered or supplied, use all the designations you can. Give the N.D. Spec. No., Fed. Std. Stock No., manufacturer's trade name, size, shape, content and use of each item.

It's particularly important that you indicate the USE for which the item is intended. Sometimes certain items are out of stock and cannot be supplied immediately. If you state the intended use, the source of supply may be able to furnish a satisfactory substitute to meet the specifications.

OXYACETYLENE FUSION WELDING RODS FOR FERROUS METALS

For oxyacetylene fusion welding of CARBON STEELS and WROUGHT IRON you will use rods of Navy Department Speci-

fication Number 46R4, Class I, Type A. These rods are available in six diameters ranging from 1/16 inch to 1/4 inch. They may be used for welding in any position. Use these rods for GENERAL WELDING of steel plates, shapes, piping, forgings and castings. No flux is required.

CORROSION-RESISTING steels (C.R.S.) of the 18-8 variety may be fusion welded with rods of Spec. No. 46R2. When you are using these rods, adjust your flame so that it is very slightly carburizing. A fluz is necessary. Use flux, Spec. No. 51F3, which is supplied in powder form in ¼, ½, 1 and 2 pound cans. This flux contains POISONOUS flourine so do your welding in a well ventilated space.

CAST IRON fusion welding by the oxyacetylene method is done with filler rods of Spec. No. 46R4, Class II, Type A. With this rod use cast iron flux, Spec. No. 51F8, Type C. You can make up this flux with a mixture of 50% salt peter, 25% soda ash, and 25% borax.

MOLYBDENUM ALLOY STEEL WELDING RODS

"MOLY" ALLOYS should be welded with a SPECIAL PURPOSE rod made of medium-carbon steel containing 1% molybdenum —Carbon-Moly steel. This type of rod carries no spec number but is listed in the Navy Department Acceptable List.

This rod is used for oxyacetylene welding of cast and wrought CARBON-MOLYBDENUM steels used aboard ship for high-pressure, high-temperature steam piping systems. It's similar to Spec. No. 46E2, used for arc-welding of the above steels.

NON-FERROUS OXYACETYLENE WELDING AND BRAZING RODS

For about 50% of all work done with the gas welding torch you will use the brazing rod specified as No. 46R1, Grade I, Class A. This rod is 58% copper and 40% zinc, with the remaining 2% made up of small quantities of manganese, tin, iron, and nickel. This alloy rod is commonly called MANGANESE BRONZE. It's used for brazing iron and steel and for fusion welding of some of the non-ferrous metals and alloys.

Manganese bronze is also used to build up wear-resisting surfaces to a hardness of about 80 Brinell or 47 Rockwell B. This rod—Spec. No. 46R1, Grade I, Class A—is the general

ALL-PURPOSE welding and brazing rod used by Navy Metalsmiths.

BRAZING FLUX for use with the above rod is specified as No. 51F8, Type A, which is furnished as powder in 1, 2, and 5 pound cans. This flux is sometimes supplied in paste form.

MONEL and PURE NICKEL are brazed to themselves or to mild steel with a rod of Spec. No. 46R1, Grade I, Class F. This class of rod is also used to provide a hard-facing of about 150 Brinell. The flux required is Spec. No. 51F8, Type B. Use a carburizing flame.

COPPER-NICKEL, both cast and wrought, may be joned with a rod of Spec. No. 46R1, Grade II, Class G. It may also be used with the carbon arc for brazing lap joints in galvanized steel. Heavy—thick—welds, however, are seldom satisfactory when made with this rod.

A COPPER BASE brazing alloy, Spec. No. 4703, containing 93% copper and 7% phosphorous may be used as a cheaper substitute for silver solder. This brazing alloy is used ONLY on copper and copper alloys. Use a neutral flame and flux—Spec. No. 51F4. This flux must not be overheated and its residue must be removed after brazing.

BRAZING SPELTER (HARD SOLDER)

Copper and nickel alloys, cast irons and steels—except C.R.S. and steels to be heat-treated — may be brazed with SPELTER of Spec. No. 46S15, Grade A (50% copper — 50% zinc) or Grade B (50% copper — 46% zinc — 4% tin). These alloys flow at about 1600° F. The torch flame should be slightly oxidizing. The flux specified is No. 51F8, Type A.

Brazing spelter alloys are available in the form of bars, wire, ingots or small lumps (grains). Brazing spelter for use on steel should be LONG grain. For use on non-ferrous metals and alloys it should be FINE grain.

FLUX FOR COPPER AND NICKEL BASE ALLOYS

These fluxes, furnished in powdered form, are specified as No. 51F8, Types A and B.

Type A is used with Grade I, Classes A and G, and Grade II, Classes A and B welding rods of Spec. No. 46R1 and brazing alloy covered by Spec. No. 46S15. This flux is also used

when you are brazing — or bronze-welding — cast iron with non-ferrous rods.

Type B (51F8) flux is for use with Grade I, Class F nickel base alloy welding rods of Spec. No. 46R1.

SILVER SOLDER ALLOYS

SILVER SOLDERS — silver-brazing alloys — are specified as No. 47S13, Grades 0, I, II, III, IV, V, and VI. All grades, except Grade III, are furnished in small strip form — forms X, A, and B. Grade III is furnished in somewhat larger strips and in the form of ⅛ inch square rods. Grades IV and VI are furnished in wire form for diameters of 1/32, 1/16, 3/32, and ⅛ inch. Grade V is supplied as octagonal or hexagonal rods in sizes ranging from 1/32 inch to ¼ inch.

While strips and rods are ordinarily supplied for shipboard use, all seven alloys may also be obtained in the form of wire, pigs, grain, shot or chips. Of the seven grades of silver solder alloys, only two are used extensively for shipboard repair work.

Grade III is used for brazing COPPER and COPPER ALLOYS only. It melts at 1200° F. and flows at 1300° F. Its composition is 15% silver—80% copper—5% phosphorous. As furnished by one manufacturer, it carries the trade name of "SilFos". A cheaper alloy that can be used for brazing copper and copper alloys is Spec. No. 47C3, which may be used as a substitute for Grade III silver solder alloy.

Grade IV is suitable for brazing virtually all FERROUS and NON-FERROUS alloys except those with melting points lower than the melting points of Grade IV. The composition of Grade IV is 50% silver—15% copper—17% zinc—18% cadmium. One trade name for this alloy is "Easy-Flo". Grade IV has the lowest melting point of all the silver solder alloys and is the most useful of all the seven grades. It melts at 1160° F. and flows freely at 1270° F.

Grades 0, I, and II alloys are used as substitutes for Grade IV for silver brazing of ferrous metals and alloys. These grades are used when their higher melting points are called for or when the volume of work makes them desirable because of their lower cost.

Grade V alloy is substituted for Grade IV for loose-fitting joints. It's used if a fillet must be built up or when consider-

able space is to be filled. Rods of Grade V are hexagonal or octagonal. A trade name for one variety is "Easy-flo 3".

Grade VI is a modified form of Grade V. One of its trade names is "Modified Easy-Flo". It is used instead of Grade V principally because it contains less cadmium, a scarce material. Use a slightly carburizing flame with Grade VI.

All of the silver brazing alloys require a CLOSE FIT of the parts to be brazed. Clearance should be less than 0.005 inch, preferably 0.002 to 0.003 inch. A thin film of silver alloy makes a much stronger brazed joint than does a thick layer of alloy.

SILVER BRAZING FLUX

Flux for SILVER BRAZING—silver soldering—is furnished in paste form in ½, 1, and 5 pound cans. It's specified as No. 51F4. This flux may be used with all seven grades of silver solder base alloys of Spec. No. 47F13, and with the substitute copper brazing alloy Spec. No. 47G3.

Silver brazing flux should be applied after cleaning and before heating of the parts. It may be thinned to the desired consistency with water. Remove all flux residues left as a result of heating. Just wash it off with water.

This flux must NOT be OVERHEATED.

ALUMINUM AND ALUMINUM ALLOY WELDING RODS

CAST and WROUGHT ALUMINUM and aluminum alloys are usually welded with rods of Spec. No. 46R7, Class B, which is available in rod sizes of 3/32, ⅛, 3/16, and ¼ inch. All alloys numbered Al-3, 52, 53, 61, and 43—the alloys you'll weld most often—are welded with Class B rods.

Other classes of rods of the same Spec. No. are —

- Class A—Used with pure aluminum (2S) or with Al-3 alloy.
- Class C—Used for foundry repair of Al–195 castings.
- Class D—Used for foundry repair of Al–195 and Al–B195.
- Class E—Limited to repair of Al-356 castings.
- Class F—Limited to repair of Al–355 castings.
- Class G—Limited to repair of Al–142 castings.

HEAT-TREATABLE alloys must be re-heat-treated AFTER WELDING to restore their original properties. NON-HEAT-TREATABLE alloys may be COLD-WORKED to obtain more desirable properties.

FLUX FOR ALUMINUM WELDING

Flux for aluminum and aluminum alloy welding is designated as Spec. No. 51F6. This flux is provided in powdered form, and should be mixed with distilled water to form a thin paste. The paste is applied to both welding rod and base metal.

Residues of flux that remain after welding must be removed completely. Since the flux contains POISONOUS flourine, aluminum welding should be done only in well ventilated spaces. And only enough flux should be mixed at a time to take care of one day's needs.

BUILDING UP WITH BRONZE

Surfaces of worn parts of many machines and tools can be built up with BRONZE. This method is used to restore the efficiency of pistons, guides, shafts, and other parts. Bronze should not, however, be used if the working temperature of the built-up surface exceeds 500° F.

Steel parts to be bronze-surfaced should be thoroughly cleaned by machining, grinding, chipping or sandblasting. Cast iron parts should NOT be machined but may be cleaned by the other methods. If cast iron parts are machined they are difficult to "tin" with bronze and a good bond cannot be established.

Alloy used for filler metal or build-up metal is usually known as bronze. But it's really a BRASS containing about 60% copper and 40% zinc. Certain bronzes, including phosphor bronze, may be used to provide special properties and characteristics of the weld metal deposit. Some of these alloys are designed to resist abrasion, others to resist high temperatures and still others to have high ductility. All of the bronze build-up alloys are readily machineable. Most of them have a melting point of about 1600° F.

Build-up of a 20 inch steel piston is shown, step-by-step, in figure 49. Machinist's mates will cut the grooves and machine the finished job to size. Your job is to apply the bronze. Fill the rough-turned grooves first and then build up the surface

with one, two, or three layers of bronze as required by the finished dimensions.

Steel parts subjected to heavy stresses and strains should be built up or resurfaced only once. Cast iron may be resurfaced as often as necessary.

When you apply a layer of bronze, keep it THIN — under ⅛ inch — and well bonded to the "tinned surface" or preceding layer. Preheating and a good brazing flux (Spec. No. 51F8, Type A) are necessary for good bonding and tinning, and clean deposited metal.

AVOID OVERHEATING — it will prevent proper tinning and

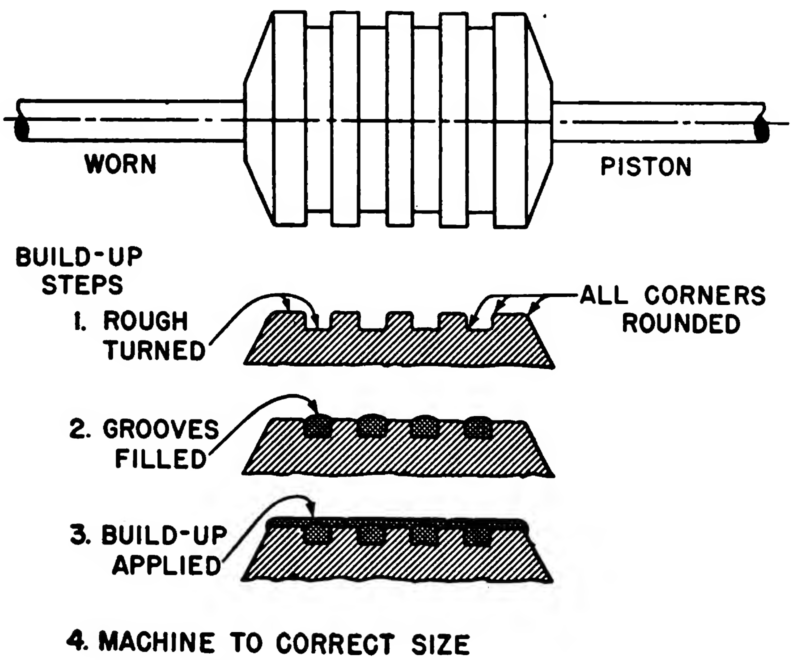

Figure 49.—Bronze-surfacing a steel piston.

bonding and may damage both the base metal and the filler metal.

When you are resurfacing with bronze or brass TWO important safety precautions must be observed—

CORED or otherwise ENCLOSED SPACES MUST BE VENTED. If not vented, they will vent themselves in a drastic manner—by a terrific EXPLOSION. Play safe by removing vent plugs or by drilling small holes through which expanding gases may escape when the part is heated.

DON'T BREATHE ZINC FUMES. Provide plenty of ventilation when you're working with brasses and bronzes because

they contain up to 45% zinc. Wear a respirator if you do much welding and brazing of zinc-content alloys. And drink plenty of MILK—it's a good antidote for zinc poisoning.

CAUSES AND CURES FOR GAS WELDING TROUBLES

You should be able to diagnose a bad weld as readily as a doctor diagnoses a bad cold. When you are able to size up a bad weld and decide WHY it is unsatisfactory, you'll be a better welder and better able to train and instruct lower-rated Metalsmiths.

Even the most expert welder sometimes makes a bad weld. When he does, he immediately ask himself "WHY"? Then he finds out WHY and starts working out a cure for the trouble. Soon he has found it and corrected the trouble. That's exactly why he's an expert.

So when you have some welding difficulty, just do a little FBI work and see if you can determine the cause of the trouble. Check the material, methods, equipment, and procedures you used. Was there some small mistake along the way?

You may find the causes of—and cures for—some of your oxyacetylene welding troubles in the tabulation that follows—

DISTORTION

Cause	Cure
Parts pulled together by shrinkage.	Clamp up or tack weld parts to resist shrinkage. Set up parts to be welded to allow for shrinkage. Peen deposited metal while it is still hot.
Buckling due to uneven or non-uniform heating during welding.	Support structure being welded to prevent buckling and sagging due to weight of parts of structure.

Cause	Cure
Wrong welding sequence.	Normalize, anneal, or stress-relieve base metal before welding. Preheat heavy parts. Revise sequence so that welding is done without excessive local heating.

WARPING OF SHEET METAL

Shrinkage of weld metal.	Distribute heat input more evenly over entire length of welded seam.
Excessive local heating.	Weld rapidly with minimum heat.
Improper joint preparation.	Use smaller gap between edges. Use flanged joints for thin metals. Slightly corrugate edge of sheet to absorb warping strains.
Wrong welding sequence.	Devise special sequence and use stepback or skip procedure.
Improper clamping.	Check method of clamping. Use back-up pieces and strips to cool parts rapidly after welding.

WELDING STRESSES

Heavy parts.	Normalize or stress-relieve.
Joints designed to be too rigid.	Develop a sequence that permits all parts to move as long as possible. Make as few passes as possible.
Improper welding procedure.	Use intermittent, alternate, stepback, or skip procedure. Clamp parts near joint and use back-up strips.

CRACKED WELDS

Cause	Cure
Joint too rigid.	Change joint design and welding procedure to lessen rigidity.
Welds too small for parts joined.	Increase size of welds by adding more filler metal.
Improper welding procedure.	Make welds full-size in sections about 8″ long. Use sequence that leaves ends free as long as possible. Preheat to reduce contraction stresses caused by local heating.
Poor welds.	Check fusion of weld metal with base metal.
Improper joint preparation.	Make joints with proper gap of uniform width and fit.

POOR WELD APPEARANCE

Improper flame adjustment or filler rod manipulation —poor welding technique.	Check technique. Avoid use of excessive heat. Use uniform weave and welding speed.
Wrong filler rod used.	Use rod designed for type of weld being made.
Joint improperly prepared.	Check joint design and preparation.

UNDERCUTTING

Excessive weaving, insufficient rod added, or wrong tip size.	Use proper tip size, modify weave, and adjust rate of welding rod melting. Use larger welding rod.
Improper manipulation of welding rod.	Avoid excessive and non-uniform weaving techniques. Keep heat input uniform.
Poor technique.	Uniform heating and filler metal deposition.

INCOMPLETE PENETRATION

Cause	Cure
Improper preparation of joint.	Allow free space at bottom of weld. Weld back of joint to insure complete fusion at bottom of V.
Welding rod too large.	Use rod of correct size to balance heat requirements.
Not enough heat—tip too small.	Select tip to suit thickness of metal being welded.
Welding speed too fast.	Reduce speed and weld at uniform rate to insure complete penetration.

POROUS WELDS

Natural properties of the rod being used.	Change to rod of proper analysis.
Improper flame adjustment and welding procedure.	Avoid overheating puddle. Check flame adjustment. Use flux if necessary.
Trapped inclusions of gas oxides and slag.	Puddle sufficiently to allow impurities to escape. Avoid large puddles by using multi-layer welding technique.

BRITTLE WELDS

Air-hardening caused by use of wrong type rod.	If ductility is desired avoid use of air-hardening filler metal. Preheat and postheat.
Too much heat, causing burned and coarse-grained weld metal.	Use smaller tip.
Wrong analysis of kind of base metal.	Check carbon content and alloy composition of base metal.
Wrong welding procedure and flame adjustment.	Adjust flame to prevent boiling, foaming or sparking of puddle.

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POOR FUSION

Cause	Cure
Wrong size rod.	Use small rod for bottom of V when you're welding thick plate.
Wrong tip size and heat input.	Use sufficient heat to break down sidewalls of weld and melt rod.
Improper welding technique.	Make sure weave is wide enough to thoroughly melt sides of joint.
Improper joint preparation.	Secure good penetration of sidewalls and root of weld.

BRITTLE JOINTS

Air-hardening base metal.	For medium-carbon steels and some alloy steels avoid rapid cooling. Check preheating temperature.
Wrong welding procedure.	Use Multi-layer welds — they tend to anneal hard zones. Stress-relieve after welding by heating to 1100-1250° F. Cool in still air.
Unsatisfactory rod.	Check analysis of rod and base metal.

UNDERWATER GAS WELDING

UNDERWATER gas welding is done with a special torch which has three leads—one for HYDROGEN, one for oxygen, and the third for compressed air. Hydrogen is used as a fuel rather than acetylene because the latter is explosive when used under water pressure.

The compressed air furnishes an AIR BUBBLE for lighting the torch and maintaining the flame.

To light an underwater torch, open the compressed air valve first. Next open and light the hydrogen. Finally, open the oxygen valve and adjust the flame.

Correct pressures for underwater welding are—

Water Depth	Air Pressure	Hydrogen and Oxygen pressure		
		Tip #1	Tip #2	Tip #3
10	20	50	60	70
20	25	55	65	75
30	30	59	69	79
40	35	63	75	84
50	42	66	80	90

(Equal hydrogen and oxygen pressures are used)

Figure 50.—Temporary bow welded on a cruiser during World War II.

A special underwater cutting torch is used for cutting FERROUS metals underwater. Hydrogen is used for fuel.

CHAPTER 6

ARC-WELDING

GAS OR ARC?

A modern battleship contains about 1000 miles of welds. That's a lot of welds, and most of them are ARC-WELDED. Shipfitters are expected to do most of the structural arc-welding aboard ship, but you may be ordered to assist them at any time. And Metalsmiths are usually expected to do the bulk of the arc-welding required by the engineering department.

When a welding job comes up, which method will you use—ARC or GAS? As a general rule, the ARC is used for fusion welding of HEAVY plates, shapes, castings, forgings, and pipe. The GAS—oxyacetylene—method is ordinarily used for fusion welding, bronze welding, brass-brazing and silver-soldering of SHEET metals and LIGHT sections of forgings, castings, and piping.

For many welding jobs the method makes little difference—just use your own judgment. When you DO have to decide which method to use, consider these factors—

> AVAILABILITY OF EQUIPMENT — You'll have to use the equipment that is supplied your ship and is available at the time you need it; it may be either a-c or d-c or you may have both.

LOCATION OF WELDING JOB — If the job must be done away from the shop, which equipment—arc or gas—is most easily and SAFELY transported? Which equipment can be used on the job with the greatest SAFETY and satisfaction?

ABILITY OF WELDING OPERATOR — If YOU are doing the job, which method would YOU use to produce the best results? Consider this point when you assign one of your men to a welding job; other factors being equal, have him do the job by the method at which he is most expert.

YOUR ARC-WELDING WORK

Most of your welding work will be done on MILD steel—that containing from 0.05% to 0.35% carbon. Methods and techniques for welding mild steel were explained and illustrated in the training course for Metalsmiths 3c and 2c. They apply as well to the welding of most other types of carbon steels, alloy steels, soft irons, and non-ferrous metals.

HEAT-TREATED parts made of plain carbon steels should be fully ANNEALED before they are welded. Such parts must be re-heat-treated—hardened and tempered—AFTER they are welded. Welding heat should be kept to a minimum for steels containing more than 0.5% carbon.

UNDERWATER WORK

You may be required—in an emergency—to do some UNDERWATER arc welding. It's not as hard as you might think. When doing underwater D-C welding, always use STRAIGHT polarity. A 5/32 inch electrode will handle the average job. For such welding, hold the electrode at an angle of 30° in the direction of travel. Allow it to keep in contact with the work and keep the tip moving just ahead of the molten metal. You'll always get a certain amount of undercut but this is not objectionable in an emergency weld.

Underwater CUTTING can be done if a stream of oxygen is used in conjunction with the arc. For such cutting, set d-c controls at 250 amps., 30-35 volts and use straight polarity.

ARC-WELDING MACHINES

Several types of ARC-WELDING MACHINES, made by different manufacturers are listed in the Navy Department Acceptable List. You may be required to use several makes of welding machines during your naval career.

Arc-welding machines used aboard ship are of the portable, motor-generator type. Their capacity is usually less than 300 amperes, so they are seldom used with electrodes exceeding ¼ inch in size.

For use and maintenance of any arc-welding machine, FOLLOW THE DIRECTIONS and INSTRUCTIONS of the manufacturer. Don't throw away the manufacturer's pamphlet that accompanies a machine. Keep it to use as a ready reference.

CURRENT VALUES FOR MILD STEEL

Few arc welders can set current values on a machine and use the first setting to complete the welding job. That's because there are so many factors that influence the arc. Good welders select a STARTING current—amperage—and then TAILOR the arc to fit the job by adjusting the current up or down.

The values below may be used as STARTING POINTS for welding steel; subsequent adjustment should be made as required—

Starting Current	Electrode Size (Amperes)
3/32″	65
1/16″	35
⅛″	110
5/32″	130
3/16″	180
¼″	220
5/16″	320
⅜″	400

Obviously if your machine has a capacity of 300 amperes, you won't be able to do much welding with 5/16 inch and 3/8 inch electrodes.

POLARITY

POLARITY for welding with HEAVY-COATED—shielded arc—electrodes is usually REVERSE—electrode POSITIVE. BARE and

LIGHTLY-COATED electrodes are usually used with STRAIGHT polarity—electrode NEGATIVE.

Most manufacturers specify the polarity to be used with their electrodes. Recommended polarity may be indicated on the electrode itself, on the shipping container, or by an enclosed instruction sheet. ALWAYS FOLLOW the MANUFACTURER'S INSTRUCTIONS if they are available.

METAL-ARC ELECTRODES

The efficiency of the METAL-ARC method of electric welding is largely due to the development of new types of electrode coatings. Most of the electrodes you will use are of the HEAVY-COATED, or shielded-arc, type.

The electrode coating acts to stabilize the arc and protect the weld metal. Two types of coating are usually used—MINERAL or CELLULOSE. A mineral coating causes a heavy layer of slag to form over the weld. This slag layer retards the rate of cooling and helps keep down cooling strains and stresses. A cellulose coating protects the weld area by forming a gaseous shield around the weld area which keeps out undesirable elements. Some electrodes may have a combination coating or be coated with special materials.

Electrodes used by Navy welders are standardized according to use and supplied according to Navy Department SPECIFICATION NUMBERS.

ELECTRODES FOR FUSING WELDING OR CARBON STEELS

Most of the CARBON STEELS are metal-arc welded with Grade I, Class 1, 2 and 3 electrodes of SPECIFICATION No. 46E3. These electrodes are heavy-coated and are used with reverse polarity. Use them to fusion weld steel plates, shapes, piping, forgings, castings, galvanized sheets and other carbon steels that are weldable.

Grade I, Class 1, electrodes come in sizes of 1/16", 3/32", ⅛", 5/32" and 3/16 inch. They may be used for welding in ALL positions.

Grade I, Class 2 electrodes come in sizes of 7/32" and ¼ inch and should be used ONLY for flat position welding and horizontal fillet welding.

Grade I, Class 3 are furnished ONLY in the 5/16 inch size and are used ONLY for heavy welding in the flat position.

Grade III, Class 1, 2, and 3 have about the same uses as Grade I electrodes.

Grade II, Class 2 and 3 are used for heavy, flat position and horizontal fillet welds. They are the ones sometimes referred to as HOT RODS. They are used—with STRAIGHT POLARITY—for welding heavy plates, shapes, castings and forgings. Class 2 may be used for both flat position and horizontal fillet welding. Class 3 in the flat position only.

Grade ED electrodes are used for HARD SURFACING. Welding deposits made with these electrodes have a hardness of about 400 Brinell and are NOT MACHINABLE.

Grade EE electrodes provide MACHINABLE hard surfacing deposits with a hardness of 200-250 Brinell. While Grade EE is not as hard as Grade ED, it is more shock-resistant.

ELECTRODES FOR CARBON-MOLYBDENUM STEELS

Grade I, Class 1 of SPECIFICATION No. 46E2 is used for welding cast and wrought CARBON MOLYBDENUM steels in all welding positions. Grade I, Class 2 may be used, with reverse polarity for making flat position and horizontal fillet welds on heavy sections. Do not use these electrodes for welding high-tensile and structural steels. Instead, use electrodes of Spec. No. 46E3.

Grade II, Class 2 electrodes may be used, with reverse polarity, for flat position welds on moly steels. Straight polarity works better when you're making horizontal fillet welds.

ELECTRODES FOR CORROSION RESISTING STEELS

Electrodes of SPECIFICATION No. 46E4 are all used—with STRAIGHT POLARITY—to weld corrosion resisting steel—"stainless"—alloys.

Grade I electrodes are for welding plain 18-8 CRS alloy. But use Grade II for welding 18-8 that has been STABILIZED with columbium or titanium. Do NOT use this electrode to weld unstabilized 18-8.

Grade IV electrodes (AC-DC) are used for GENERAL SHIPBOARD welding of SPECIAL TREATMENT steel (STS), armor, and other air-hardening alloys. They're also for welding 25-20 scale-resisting alloy when used in high temperature applications. Grade IV (AC-DC) may be substituted for Grade I and Grade II.

Grade IV (DC) are used at SHORE establishments for welding STS, armor and other air-hardening alloys.

Shore establishments also use Grade V for welding STS—up to 1 inch thick—to itself when installed in bulkheads, and the like, for splinter protection. Grade V is NOT used where structural strength of the ship is involved.

COPPER BASE ALLOY ELECTRODES

Grade I, Class 2 electrodes—copper-nickel—of Spec. No. 46E5 are used ONLY for welding cast and wrought COPPER-NICKEL alloy such as you find in salt water piping systems. Flat position and horizontal fillet welds can be made. Use REVERSE polarity.

Grade I, Class 2—phosphor-bronze—is used for general welding of copper and LOW-STRENGTH bronzes and brasses. This grade can also be used for brazing iron and steel and for application of a bronze-surfacing with a hardness of about 90 Brinell.

For general welding of HIGH-STRENGTH bronzes and brasses, particularly manganese bronzes, use Grade III, Class 3 electrodes—aluminum bronze. Grade III can also be used to deposit a bronze-surfacing of about 120 Brinell.

ELECTRODES FOR NICKEL-COPPER ALLOY

Grade A electrodes of Spec. No. 17E4 may be used in all positions and Grade B in the flat position for welding MONEL and PURE NICKEL to themselves or to black or galvanized steel. These electrodes are also used to weld copper or copper-nickel to themselves or to steel, for repairing iron and steel castings, and for hard-surfacing to a hardness of approximately 150 Brinell. Do NOT use them for welding 18-8 "stainless" steels.

ELECTRODES FOR ALUMINUM AND ALUMINUM ALLOYS

Grade I, Class 2 and Class 3 electrodes, Spec. No. 46E1, are made of Al-2—commercially pure aluminum. This grade is used for welding PURE ALUMINUM and in applications requiring maximum corrosion resistance. Class 2 may be used in flat position welding and for horizontal fillets. Use Class 3 only for flat position welding.

Grade II electrodes are suitable for welding aluminum and

most of the NON-HEAT-TREATABLE alloys. The low strength of the weld made with one of these electrodes can be increased only by cold-working. These electrodes can be used for welding some of the heat-treatable alloys, IF strength is not required. Class 2 of Grade II electrodes are suitable for flat position and horizontal fillet welding, but Class 3 of Grade II electrodes may be used only in flat position welding.

CARE AND STOWAGE OF COVERED ELECTRODES

Old time gunners and riflemen used the motto "Keep your powder dry". The welder's version might well be "Keep your COVERED ELECTRODES dry". If covered—heavy-coated or shielded—electrodes are exposed to moisture, the coverings will absorb moisture and deteriorate—lose their properties.

Dampness in electrodes may not be apparent to sight or touch. But try to use a damp electrode—it will probably spatter excessively and the coverings may pop off because of the steam formed under them.

Aluminum electrodes require the greatest care because their coverings dissolve if much moisture is absorbed. Wet mild steel and CRS electrodes may be salvaged by drying them for several hours, at a temperature of 90°.

Electrodes should be stored ONLY in DRY locations. Coverings will absorb moisture from air as well as from exposure to rain, salt water, and condensation drips from piping and bulkheads.

Keep covered electrodes sealed in the original package until their use is required. Avoid handling or stacking electrodes in any manner that will break or crush the coverings.

AVOID OVERSTOCKING—covered electrodes deteriorate after a few months, even when kept dry.

GRAPHITE CARBON-ARC ELECTRODES

GRAPHITE electrodes—Spec. No. 17E1—for carbon-arc welding and brazing are manufactured in sizes ranging from 1/8 inch to 1 1/2 inch but the 3/8 inch size is usually the only one furnished for shipboard use. This electrode will handle any job—welding or cutting—for which you require the carbon-arc method.

The carbon-arc is more efficient than the oxyacetylene torch

for cutting—melting—CRS and non-ferrous metals and alloys. Straight polarity is always used with the carbon arc. Use of reverse polarity will cause the electrode to burn away rapidly.

The carbon-arc method is not used extensively by Navy welders. For welding, it is, generally speaking, similar to, but not as satisfactory as oxyacetylene.

PREHEATING FOR METAL-ARC FUSION WELDING

PREHEATING for arc welding may be done with the oxyacetylene torch. It's more economical, however, to use an OIL-BURNING torch. One type is pictured in figure 51. This same type may be used for postheating.

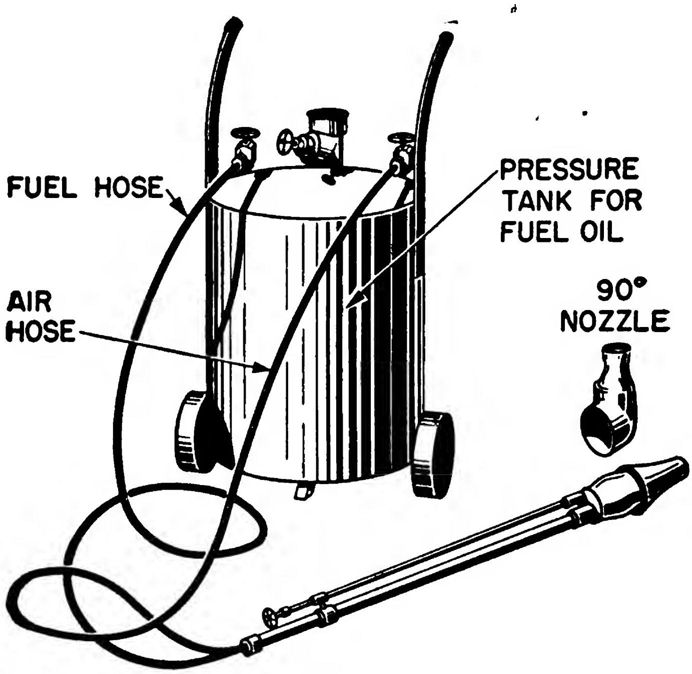

Figure 51.—Portable oil-burning preheating torch.

No preheating is necessary for the metal-arc welding of WROUGHT IRON, LOW-CARBON iron (soft, black), GALVANIZD steel or iron, HIGH-ALLOY CHROMIUM-NICKEL steels (CRS), or LOW-CARBON sheets.

Carbon steels require NO preheating when they are welded with electrodes of Spec. No. 46E4 (CRS). For other electrodes used in welding carbon steels, preheat—

Low-carbon steels up to 30°F;

Medium-carbon steels to 300–500°F;

High-carbon steels to 500–800°F;
Tool steels up to 1000°F.

Low-alloy nickel steels (3 to 3½% nickel) and low-alloy nickel-chromium steels (1 to 3½% nickel—0.20% chromium) do not require preheating but do need slow cooling.

Alloy steels containing molybdenum or manganese should be preheated to 300-400°F. for fusion welding.

Cast carbon steel should be preheated to 200°F. for fusion welding. Gray cast iron and alloy cast irons should be preheated to 700-800°F. for fusion welding.

To weld copper, it should be preheated to 500-800°F., and phosphor bronze, silicon bronze, aluminum bronze and other bronzes to 200-300°F. Aluminum (Al-2) and aluminum alloys (Al-3 and Al-52) should be preheated to 500-800°F. Al-51 and Al-53 may be preheated up to 400°F.

PREHEATING FOR METAL-ARC BRAZING

Wrought iron and galvanized steel and iron require no preheating. Low-carbon steels may be preheated up to 300°F. Cast carbon steels should be preheated to 200°F, and gray cast iron and malleable iron up to 500°F.

CARBON-ARC WELDING OF NON-FERROUS METALS

Brasses and bronzes may be carbon-arc welded with a phosphor bronze filler rod. A brazing flux is required. Preheat the base metal to 200–300°F.

Deoxidized sheet copper should be preheated to 500-800°F. and welded with a heavy-coated deoxidized copper, phosphor bronze or silicon bronze filler rod. No flux is required.

Preheat beryllium copper to 500–800°F. and weld with a heavy-coated beryllium copper filler rod. No flux is necessary.

CAUSES AND CURES FOR ARC WELDING TROUBLES

Causes of, and cures for, distortion, warping, and welding stresses are about the same for arc welding as for gas welding. Suggested causes and cures for other arc-welding troubles are outlined below—

POOR WELD APPEARANCE

Cause	Cure
Bad welding technique — improper current setting or electrode manipulation.	Use proper electrode. Avoid use of excessive current. Use uniform weave and travel.
Welding in position for which electrode was not designed.	Check specifications for electrodes. Change position of welding, if possible.
Improper joint preparation.	Prepare joints correctly.

CRACKED WELDS

Joint too rigid.	Change welding procedure and design, if possible.
Weld too small for size of joined parts.	Increase size of weld by adding more filler metal.
Wrong procedure.	Plan welding so that ends are free to move as long as possible. Preheat.
Poor welds.	Secure better fusion and sound welds.
Wrong spacing or gap	Check polarity and arc length. Prepare joint with proper gap or free space.

UNDERCUTTING

Welding current too high.	Adjust to lower current and reduce welding speed.
Improper manipulation of welding electrode.	Use smaller size electrode. Keep puddle smaller. Avoid excessive weaving. Check angle of electrode when making horizontal fillet welds.
Wrong position for electrode.	Use electrodes only in positions for which they are designed.

INCOMPLETE PENETRATION

Cause	Cure
Wrong joint preparation.	Allow proper spacing. Use back-up bar or strip. Chip groove along back of weld, lay bead in groove.
Electrode too large.	Use smaller electrode for better penetration.
Current too low.	Increase current or reduce speed of electrode travel.
Welding speed too fast.	Reduce speed to rate that insures complete penetration.

POROUS WELDS

Electrode properties.	Use specified electrode or recommended substitute.
Wrong procedure.	Use wide weave rather than narrow string beads. Avoid excessive current
Entrapped gases.	Puddle to keep weld metal molten long enough to allow escape of entrapped gases.
Defective base metal.	Use better grade of material.

BRITTLE WELDS

Unsatisfactory electrode.	Use coated electrode for ductile welds.
High current, causing burnt and coarse-grained weld metal.	Reduce current.
Base metal unsuitable for welding (carbon too high).	Avoid welding if possible. Use multiple-layer welds. Try other types of electrodes.

POOR FUSION

Cause	Cure
Wrong electrode diameter.	Use small electrode in narrow V's.
Improper current.	Adjust current. Heavy plates require lower current for a given diameter electrode than light plates or sheets.
Weave too narrow.	Widen weave to insure complete melting of sides of joints.

MAGNETIC BLOW

Magnetic field of arc.	Change ground, and ground in two or more places. Weld toward direction of arc blow. Use shorter arc. Change angle of electrode. Loop ground lead around work.

SPATTER

Excessive welding current.	Shorten arc and use lower current.
Certain types of electrodes tend to spatter.	Paint parts adjacent to weld with whitewash or similar coating. Globules of molten metal will then cool without fusion.

ARC WELDNG SAFETY PRECAUTIONS

Never strike an arc unless your HELMET is IN PLACE. Remove INFLAMMABLE material from the vicinity of welding, and keep a FIRE EXTINGUISHER handy AT ALL TIMES. Do NOT strike an arc on a COMPRESSED GAS BOTTLE or on any other container, such as a gear box. Deposit HOT electrode STUBS in a safe place.

Avoid welding where the air is not CLEAN and DUST-PROOF. Always provide PLENTY of VENTILATION, particularly when

welding and brazing with non-ferrous alloys containing zinc and lead.

You should wear SAFETY GOGGLES for chipping, grinding and peening and leather GLOVES with gauntlets and asbestos or leather JACKETS and APRONS to prevent burns due to heat, spatter, and infrared or ultra-violet rays. Wear DUNGAREES with legs that are LONG enough to prevent gobs of molten metal from falling into your shoes.

Keep all GEAR FREE OF OIL AND GREASE. Any material soaked with oil is easily ignited or scorched.

Figure 52.—Welder wearing helmet, gloves and leather jacket.

Use portable SCREENS to protect your fellow workers, and warn bystanders NOT TO LOOK AT THE ARC. Make sure that your helpers are equipped with helmets and suitable clothing for that particular job.

Do **NOT** weld containers that have held INFLAMMABLE MATERIALS. Do NOT attempt to preheat or weld CORED OBJECTS or objects having INCLOSED SPACES without proper VENTING. These last two precautions are MOST IMPORTANT. Failure to observe these precautions religiously has cost many welders arms, legs, eyes, ears—even their lives.

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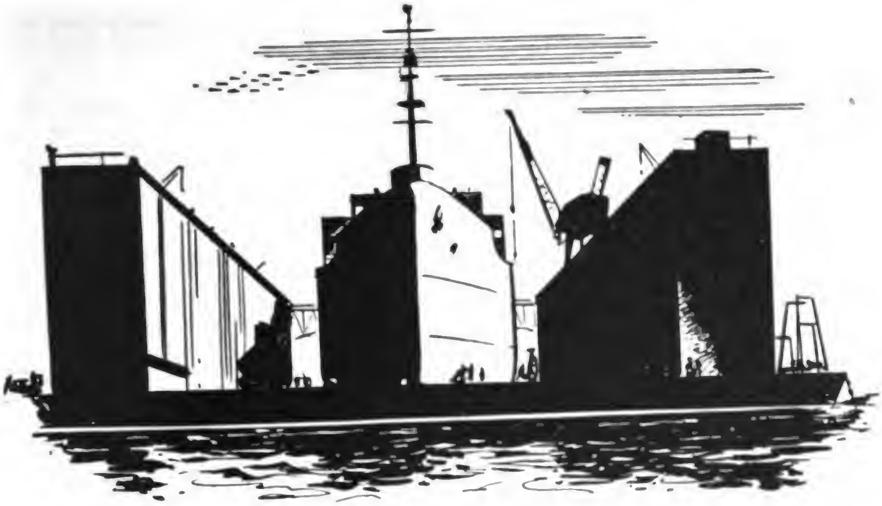
SAFE OPERATION OF EQUIPMENT

As important as the above precautions is a knowledge of how to OPERATE your equipment safely. Remember, first of all, NOT to change CURRENT SETTINGS while the arc-welding machine is operating under load.

Always make sure you have a good GROUND CONNECTION. Use bolts or tack-weld if necessary. Have electrician's mates check circuits and make necessary electrical repairs.

NEVER OVERLOAD the machine. Keep the electrode holder, when not actually in use, on an insulated hook or lay it on insulating material.

Inspect your CABLES frequently for loose connections and damaged insulation. Do NOT drag leads—cables—haphazardly through doors, hatches, and manholes, or around corners and up ladders. Get a helper to assist you. Lastly, store the welding machine in a DRY, DUST-PROOF place to avoid damage to bearings and electrical windings.



CHAPTER 7

HARD-FACING

SAVING THE SURFACE

Working surfaces of many metal objects, such as cutting tools, machine parts and valve facings, wear away and lose their usefulness. The wear is caused by FRICTION—abrasion—or is the result of IMPACT—blows. Such worn parts may be resurfaced with special abrasion-resistant and shock-resistant alloys.

The process of resurfacing is called either HARD-FACING or HARD-SURFACING. Even brand-new parts are sometimes surfaced or resurfaced before they are placed in service.

Hard-surfacing material is usually so applied that it forms a THIN LAYER over the base metal. The thickness of the deposit is usually from 1/16 to 1/8 inch, and seldom over 1/4 inch. Applications on small parts are ordinarily made with an acetylene torch. Some hard-surfacing alloys are also available in the form of electrodes for metal arc welding. All these alloys are highly resistant to corrosion.

MATERIALS FOR HARD-FACING

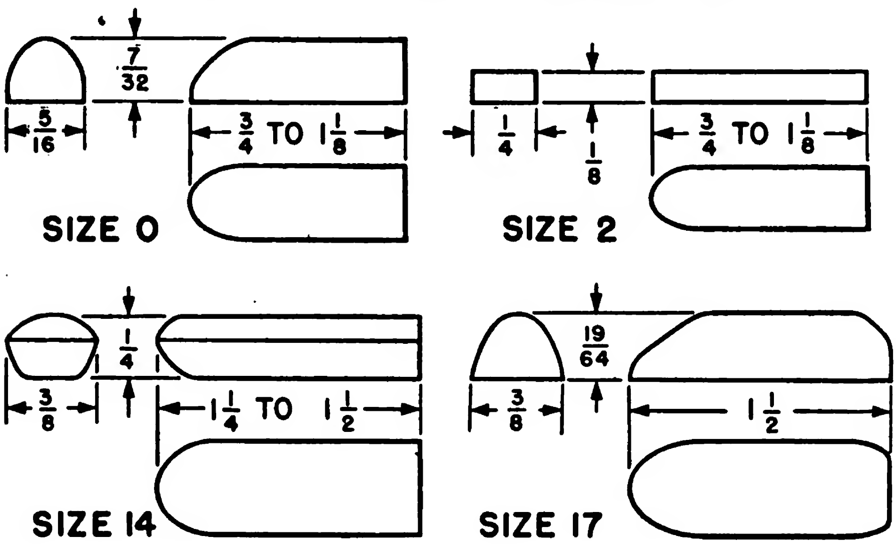
There are THREE general types of hard-facing materials. IRON BASE ALLOYS, which contain nickel, chromium, manganese and other hardening elements, come in rod form and are fused

to the base metal by welding. They melt at about the same temperature as steel.

TUNGSTEN or COBALT alloys are also furnished in rod form. They are sweated to the base metal by a process similar to that used for bronze-welding.

TUNGSTEN CARBIDE is furnished in the form of small cast inserts. The inserts are not melted but are held in place by weld metal built up around them. This is the hardest facing material—almost as hard as a diamond.

HAYSTELLITE TUNGSTEN CARBIDE INSERTS



MANY OTHER SIZES AND SHAPES ARE AVAILABLE

Figure 53.—Tungsten carbide hard-facing inserts.

Alloys used for hard-facing are manufactured under many trade names. Some of them are Stellite, Colmonoy, Blackor, Manganal, Borod, Carboloy, Haschrome, and Stoodite. In the following table (figure 54) the hard-facing products made by two different companies are compared and arranged into five groups according to characteristics and use.

Haynes STELLITE (Group 3) is used extensively and is available in THREE standard grades—

GRADE NO. 1 is extremely hard and has the greatest wear—abrasion—resistance. It's so hard it may chip or crack if it's subjected to extreme pressure or heavy shocks.

HARD-FACING MATERIALS

Group	Stoody Products	Haynes Products	Characteristics and Uses
1	STOODEX STOODY SELF-HARDENING	HASCHROME	Iron base. 50% to 80% iron, 20% or more of alloying agents. Used where toughness and shock resistance are important. May be used as base for other hard-facing alloys.
2	STOODY SELF-HARDENING STOODITE	HASCHROME	Similar to group 1 but harder and less resistant to shock though more resistant to abrasion.
3	SILFRAM STOODITE	STELLITE	Non-ferrous alloys of chromium, tungsten, cobalt and other non-ferrous metals. Available in several grades for a wide variety of application.
4	BORIUM COBALT BORIUM	HAYSTELLITE	These are diamond substitutes. Extremely hard and wear resistant. They are made of almost pure tungsten carbide. Furnished in the form of small cast inserts. High melting temperature—well above that of steel.

Group	Stoody Products	Haynes Products	Characteristics and Uses
5	TUBE BORIUM BOROD	HAYSTELLITE	Similar to group 4 but furnished in the form of crushed particles or powder. Particles are contained in tube or imbedded in steel rods. Particles do not melt but are held in place by surrounding weld metal.

Figure 54.—Hard-facing alloys arranged by groups.

GRADE NO. 12 is softer than No. 1 and less resistant to abrasion. However, it is stronger, tougher, more ductile, and more resistant to shock or impact.

GRADE NO. 6 is stronger than either No. 1 or No. 12. While its abrasion resistance is somewhat lower, No. 6 does not check or crack easily from shock or impact. It's better able to stand up under sudden temperature changes. That's why it's used for valve facings on high-pressure, high-temperature steam lines.

The Navy Department Spec. No. 46R5 hard facing rod is the standard material for application to high-pressure, high-temperature valve seats and disks. It's also used to face engine exhaust valve seats, disks, and other valves.

METALS WHICH CAN BE HARD-SURFACED

Low-carbon and medium-carbon steels and low-alloy steels are easily hard-surfaced by either the torch or arc method.

High-carbon steels can be faced if they are first annealed. They must be heat-treated after they've been hard-faced. Minimum penetration is advisable.

It is NOT advisable to attempt to hard-face high-speed steels because the heat required for application damages the base metal. Corrosion-resisting steels and Monel metal are easily hard-faced by either the oxyacetylene or arc process. CRS

must be heated and cooled UNIFORMLY to avoid warping and cracking.

Cast iron—gray and alloy—may be hard-faced with either method—gas or arc. Care must be taken on thin edges because the melting point of cast iron is somewhat below that of steel.

Malleable iron is seldom faced because the heat required for hard-facing will cause the base metal to become harder and more brittle.

Brasses and bronzes are difficult to hard face because their melting points are considerably below those of the hard-facing alloys. Limited applications are possible with the metal-arc method.

Aluminum and aluminum alloys CANNOT be hard-faced.

PREPARATION OF BASE METAL

Metal surfaces to be hard-faced should be cleaned of all dirt, scale, and rust by grinding, machining or chipping. In a pinch you can file, wire brush or sandblast, but the other methods produce best results.

Edges of grooves, corners or recesses must be well rounded to prevent overheating of the base metal and to provide a good cushion for the hard-facing material.

PREHEATING, when required, is done in the same manner for hard-facing as for fusion welding. If preheating is necessary for good welding, that's your cue to preheat for hard-facing.

After a piece of steel is hard-faced, it should be heated to its critical temperature and quenched in OIL. Don't quench in water because too rapid cooling will crack the layer of hard-facing material.

HARD-FACING WITH THE TORCH

Use of the oxyacetylene flame allows CLOSE CONTROL of the hard-facing operation and produces a smooth deposit. Scale and foreign matter are easily eliminated by this method, and edges and corners are readily formed. This is important when the hard-facing must be finished—ground—to close limits.

Degree of PENETRATION can be accurately controlled with the flame method. This is important because some facing alloys must be fused and puddled into the base metal, while

others are merely sweated onto it.

The torch tip size for hard-facing should be about two sizes larger than that used for welding with the same size of welding rod.

Now take a look at how the process of hard-facing with a torch varies according to the characteristics of the five different groups of facing products listed in figure 54.

When using the products in GROUP 1 the flame should be CARBURIZING. This increases the hardness of the deposit. You should puddle the hard-facing rod into the base metal just enough to secure good fusion. For greatest hardness, cool slowly after application. For a softer—but tougher—facing, quench in oil when the temperature is just below the melting point.

Handle GROUP 2 in a similar manner to group 1, except that deeper penetration and more puddling is permissible. The acetylene feather or streamer should be two to three times the length of the inner cone of the flame.

The alloys in GROUP 3 are non-ferrous and are applied by SWEATING. The surface of the base metal—steel—should not be melted at all. Do not stir or puddle the rod. Control the thickness of the deposited metal by manipulation of the flame. Only a small area should be faced at one time.

GROUP 4 alloys are of the insert type and should NOT be melted at all. The process for using them is sometimes called "hard-setting". To apply an insert, first stick it to the molten end of a high-test steel welding rod. Then melt the base metal and push the preheated insert into place. You should then surround and cover the insert with the steel which is melted from the high-test rod. Repeat the process for each insert.

Crushed tungsten carbide is used to make the alloys in GROUP 5. As explained in figure 54, particles are imbedded in steel strips or rods, or used to fill steel tubes. For application the surface of the base metal should be melted and the hard-facing rod stirred to distribute the crushed particles in the deposited metal.

HARD-FACING WITH THE ARC

Hard-facing alloys of groups 1, 2, and 3 may be applied with the arc if REVERSE POLARITY is used. Coated electrodes are the general rule with this process. They reduce spatter loss, assure good penetration, prevent oxidation of the de-

posited metal, and help to stabilize the arc. Bare electrodes may be used for heavy work.

Keep the arc as long, and the voltage as high, as possible. You may use the following table as a general guide for current settings—

Size of Electrode	Current
1/8 inch	100 to 150 amp.
3/16 inch	150 to 200 amp.
1/4 inch	200 to 250 amp.

Group 4 and Group 5 hard-facing alloys may be "set on" with heat provided by a carbon arc. Set the welding machine for a STRAIGHT polarity. The process is much the same as for oxyacetylene torch application of the same materials.

FINISHING BY GRINDING

Hard-facing deposits are so hard they cannot be filed or machined. They must be ground to size and shape. Because of their extreme hardness, they should be built up only slightly

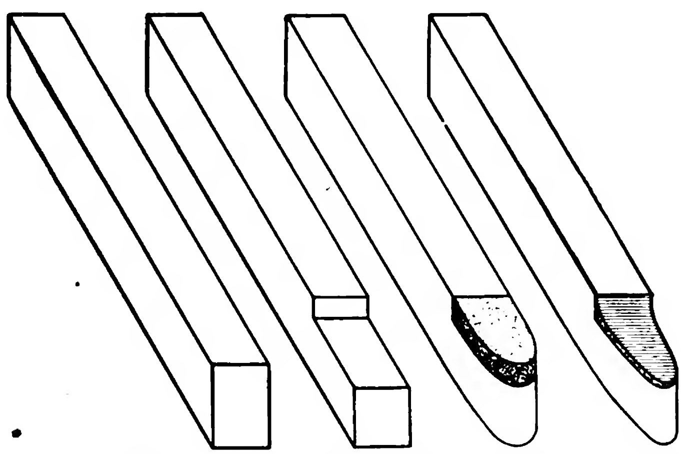


Figure 55.—Hard-facing a lathe cutting tool.

larger than the exact size, thus eliminating unnecessary grinding.

Use a soft grade, vitrified bonded, 46 to 60 grit wheel for grinding hard-facing deposits. The SURFACE SPEED of the wheel should be from 2,800 to 4,200 surface feet per minute. Remember—don't confuse surface speed with revolutions per minute.

PRACTICAL APPLICATIONS

Aboard ship you may be called on to apply hard-facing alloys to lathe centers, lathe cutting tools, shaper tools, hand snip blades, shear blades, gate and globe valve facings, engine valves and seat rings, and to other parts and tools.

New lathe and shaper tools may be made and hard-faced by the method shown in figure 55. The hard-facing alloy you use will be determined by the kind of alloys available and by the expected use of the tool.

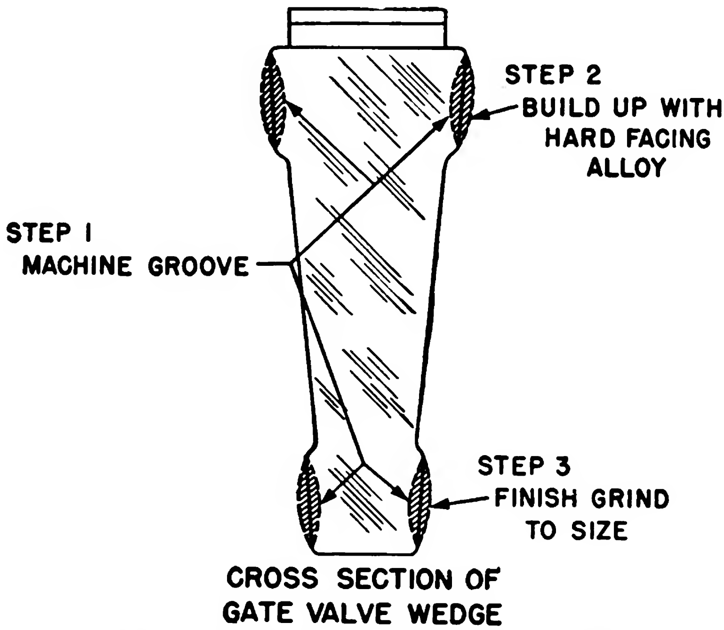


Figure 56.—Hard-facing a gate valve wedge.

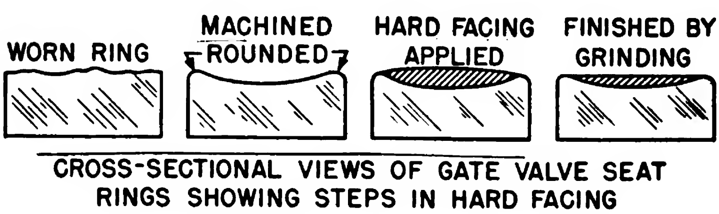


Figure 57.—Hard-facing a valve seat ring.

Cheaper lathe tools are sometimes made of ordinary mild steel and then faced with high-speed tool steel. The mild steel provides a tough, shock-resistant backing for the more brittle tool steel edge.

Worn gate valve wedges may be resurfaced with hard-facing alloys. The faces of the wedge should be machined to the

shape shown as STEP 1 in figure 56. Notice how the edges and corners are rounded before the hard-facing alloy is applied.

Gate valve seat rings are hard-faced by the method shown in the cross-sectional views of figure 57. Other types of valve fittings are faced in a similar manner. Such jobs must be dressed or finished with precision grinding equipment.

CHAPTER 8

METAL TESTS

MODERN METAL TESTING

Long ago man devised simple methods of TESTING METALS. In the days of John Paul Jones, the blacksmith tested cold metal by hitting it with a hammer and listening to the ring. He also used simple indentation and file tests. The guns of that time — clumsy, short-barreled muzzle-loaders — were tested ashore with extra heavy powder charges.

Such simple tests are still used extensively today, but they have been supplemented by modern scientific methods. Steel mills, foundries, shipyards, engine works, Navy Yards, repair ships and advanced bases usually have special METAL LABORATORIES in which metals, manufactured parts and assemblies are tested to determine accurately the properties of the metals. Most of the special testing required by the Navy is done at Navy Yards by skilled civilian technicians.

You may be called on to use metal testing equipment if it is available; for instance, if you are billeted in a repair ship. This equipment is easy to use if you follow the manufacturer's instructions. You must remember, however, that such equipment is designed for PRECISION WORK and that the parts are made and fitted with the utmost accuracy. Therefore, testing machines must be handled and used with the greatest care.

Never force any machine, and be very careful not to drop any of the parts or accessories.

When you make a metal test, your purpose will be IDENTIFICATION — or to determine such properties as HARDNESS, STRENGTH or DUCTILITY. You'll ordinarily use simple items of equipment you normally have at hand—grinders, files, hammer and vise—for the following tests:

TYPE OF METAL TEST	METHODS AND EQUIPMENT USED
Hardness	Determined by file test, grinder test or by use of special testing machines.
Tensile Strength	Determined by rupturing specimen under tension provided by "pull-test" machine.
Ductility	Determined by free bend test and by percent of elongation as indicated by tensile test.
Weld Soundness	Determined by visual inspection, nick-break test, guided-bend test and by microscopic inspection of polished and etched surface.

Other tests, usually made only in laboratories, and requiring much more equipment, are—

Type of Test	Testing Method
Grain Structure	Inspection of etched sample under microscope, or by photographs made through the microscope.
Density of Weld Metal	Computed from weight and volume.
Shear Strength	Determined by rupturing longitudinal and transverse filled welds under tensile load and by special machines.
Impact Resistance ...	Special machines.
Fatigue Resistance ...	Determined in special machines which apply repeated applications of loads.
Corrosion Resistance..	Determined by accelerated etching in corrosive acid solutions and by running tests over long periods of time.

Most of your welded construction aboard ship must have a certain TENSILE STRENGTH. The usual procedure for determining this strength is to insert a test piece of the metal between the jaws of a suitable testing machine and to increase the load gradually until the metal breaks. (When making a tensile test, be sure the safety pin is in place to prevent the ruptured test piece from flying out.) The tensile strength thus obtained is the maximum strength of the metal UNDER TENSION, or the force actually required to pull it apart.

But it's not that easy to express the tensile strength in pounds per square inch. The CROSS SECTION of the test piece must be

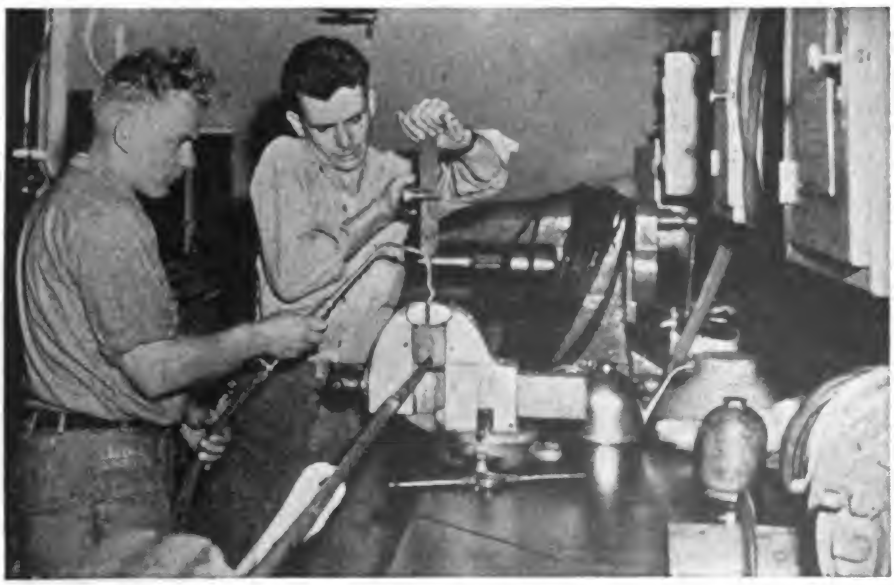


Figure 58.—Know how to test the metal you use.

considered. The length does not affect the result. So, in testing a piece of metal, measure the width and thickness, and calculate the cross-sectional area of the test specimen in inches by multiplying these two figures.

Suppose, for example, you have to test a bar 8 inches long by 1¼ inches by ¼ of an inch. The cross section of the bar is—

1¼ inches × ¼ inch = 5/16 square inches

When you know this, mount the test piece in a machine which will exert a smooth pull of sufficient power to break the specimen. The testing machine may be either stationary

or portable. Figure 59 shows a machine of the portable type with a test piece inserted in the jaws. The load applied to the test piece is registered on a gage located on the machine.

To find the tensile strength of the bar, record the load that it took to break the bar. Let's say it's 18,000 lbs. DIVIDE this breaking load by the original cross sectional area of the piece. Like this—

$$18{,}000 + 5/16 = 18{,}000 \times \frac{16}{5} = 57{,}600$$

Thus your test piece has a tensile strength of 57,600 psi.

Several other changes take place during the test, which are often used to compute such factors as yield point, percentage of stretch, and reduction of cross-sectional area. The YIELD

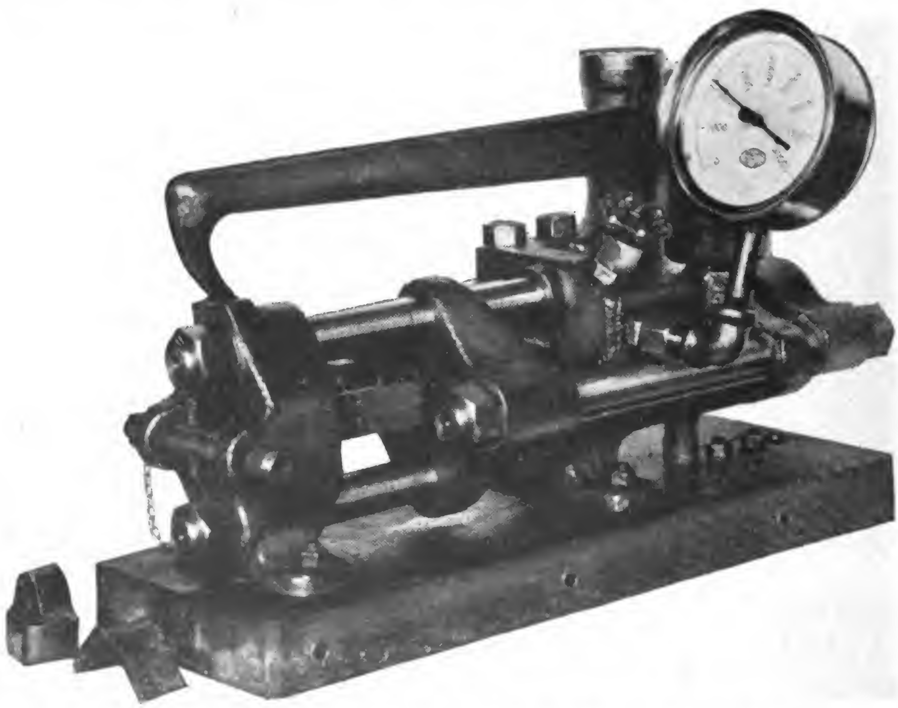


Figure 59.—Airco portable tensile testing machine.

POINT is the point at which a definite increase in LENGTH of the specimen occurs with no increase in load. The load at this point expresses the yield point.

The ELONGATION is determined by removing the test piece from the machine, fitting the broken ends together, measuring the distance between the gage marks and subtracting the gage

length. By dividing the elongation by the gage length, you'll get the PERCENTAGE OF STRETCH.

FREE BEND TEST

Another way of measuring the ductility of metal—and the one that is preferred, particularly in determining the ductility of a completed weld—is the FREE-BEND test. Here's the procedure.

Take a test piece like that shown in figure 60. Grind the top of the weld flush with the surface of the base metal. The scratches produced by the grinding should run across the weld in the direction of the bend. On the face scribe a line 1/16 inch in from each edge of the weld. Measure the distance between the lines in inches to the nearest 0.01 inch. Let the resulting figure equal X.

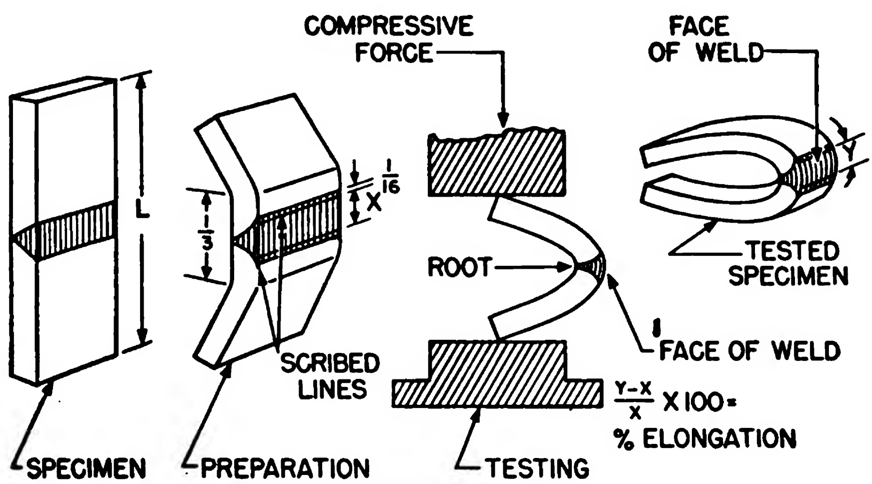


Figure 60.—Free-bend test.

With the scribed lines at the outside, bend the piece so that all the bending occurs IN THE WELD. This is easy if you clamp the piece in a vise with one-third of the length of the piece projecting from the jaws and bend the end away from the gage lines at an angle of approximately 30 degrees. Bend the other end the same way. The piece, bent one-third of the length in from each end, should look like the sample in figure 60.

The test is not over yet. Bend the test piece in an hydraulic press or similar machine. Pieces less than ¼ inch in thickness can be tested in a vise. As soon as you see a crack in

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the weld surface, stop the bending and measure the new distance between the lines. Let that equal Y. The percentage of increase in length—ductility—is therefore—

$$\frac{Y - X}{X} \text{ times } 100$$

The requirements for the metal to pass this test are that the minimum elongation shall be 15 percent and no cracks greater than 1/16 inch shall exist on the face of the weld.

BACK BEND TEST

The BACK BEND test is similar to the free bend test. The pieces, however, are bent so that the ROOT of the bend is on

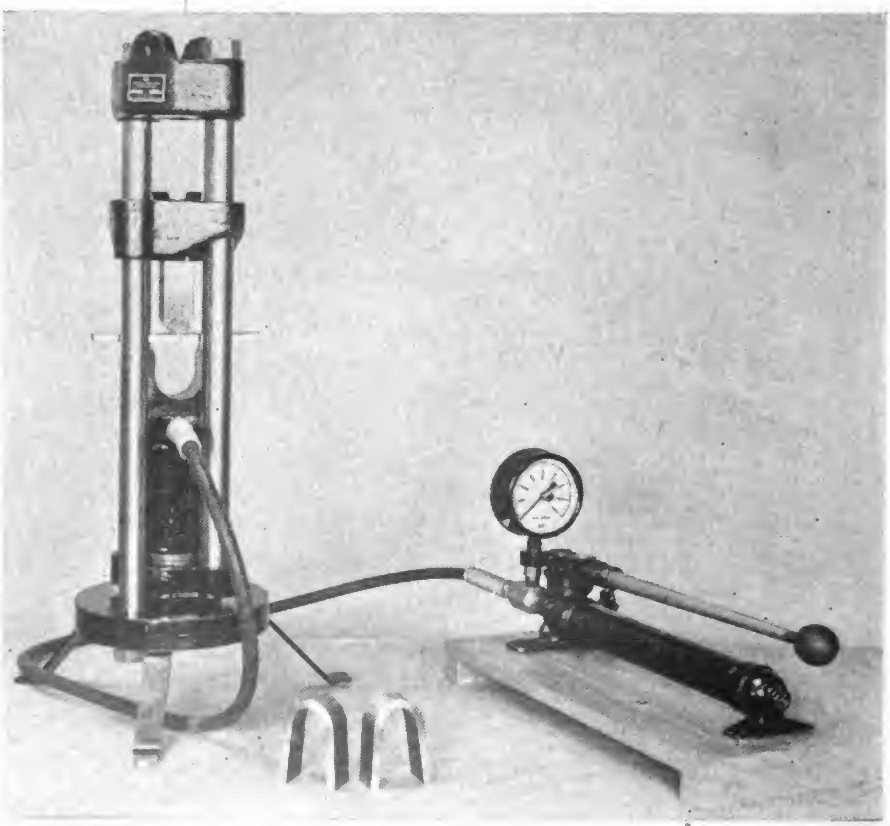

Figure 61.—Keep the weld directly in the center of the bend.

the OUTSIDE as shown in figure 62. The pieces are required to bend 90 degrees without breaking apart. Both the back bend and the free bend tests are less used than the guided bend test in qualifying a man for welding.

TENSILE AND GUIDED BEND TESTS

The GUIDED BEND test is used to determine the soundness of welds. Figure 61 shows a tensile testing machine used to make such tests. Many of these machines are used in welding schools and laboratories for daily testing of specimens.

This machine is simple in construction and easy to use. All you need do when you are ready to make a test is pump the

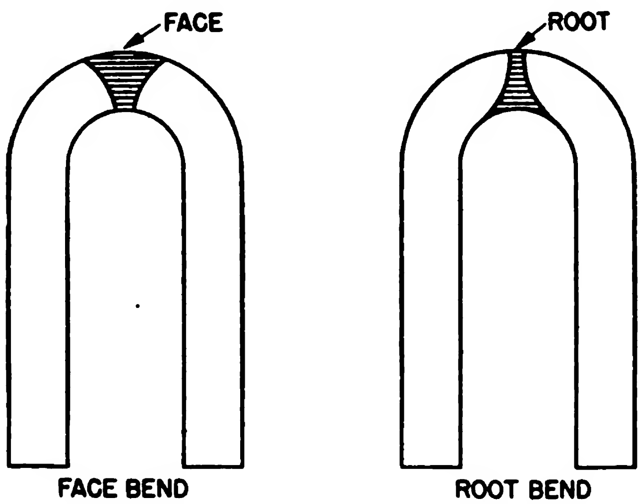

Figure 62.—Guided bend tests.

lever of the pump. You can apply a direct load up to 40,000 lbs., and even higher on small specimens. On the large gage you can watch the load grow. You know the actual load under which the test piece fails by the position of an auxiliary hand which is carried along by the gage pointer. The hand remains at the point of maximum load after the pointer returns to zero. The whole operation is rapid, simple, and sure.

The test piece, properly machined, is placed across the supports of the die and plunger with the weld at midspan. If you have not tried this test before, be careful not to let the test piece fall off the die. Pump the plunger up so that the metal piece bends and assumes the shape of the jig.

To pass the test, the specimen must have no cracks greater than ⅛ inch in dimension, on the surface.

Two different guided bends are made in this jig. One—the

FACE BEND—is made with the face of the weld in tension (outside). The other—called the ROOT BEND—is made with the root in tension. Both are illustrated in figure 62.

This machine is also used to make a TRANSVERSE TENSION test. To prepare the machine for this test, you have to remove the guided bend test plunger, and in some cases the die, so that they will not interfere with tension testing. Next, insert two test jaws into the heads, one each in the fixed and movable heads. When inserting the jaws, be sure that the toothed surfaces face each other.

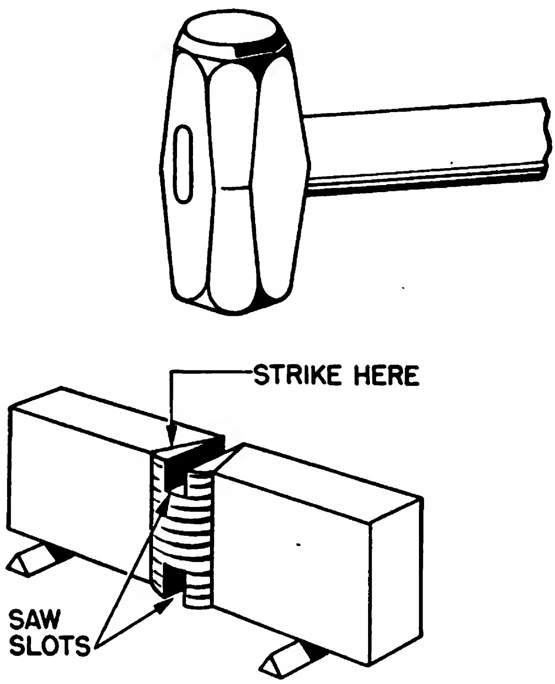

Figure 63.—Nick-break test.

Take your test piece and insert one end in the movable head first. Check the position of the specimen relative to the jaws and to the tapered seat in the head. It must be correct. The full face of the jaws must grip the specimen, and the jaws should always be even with each other. Pieces over ½ inch thick will not fit well in the jaws. Be sure you insert the safety pin at the top of the machine before you apply any tension.

NICK-BREAK TEST

The NICK-BREAK test is also used to determine the soundness and ductility of weld metal, although less frequently than the guided bend. It reveals slag inclusions, gas pockets, lack of fusion, or other internal defects in weld metal.

In figure 63, you see a test piece which has been taken from a welded joint, machined and each edge of the weld slotted. The edges were sawed through the center before the piece was supported on two steel blocks.

What's the next step? The illustration gives you an idea. Hammer the piece at the top of the slot until the weld between the slots fails, thereby exposing the interior of the weld metal. Examine the fractured weld for slag inclusions, gas pockets, lack of fusion, and so forth.

The requirements for passing this test are pretty easy. The size of any gas pocket that you find in the fracture must not be greater than 1/16 inch, and the number of gas pockets must not exceed six per square inch of the weld area.

HARDNESS TESTING

Most metals possess some degree of HARDNESS—that is, ability to resist penetration by another material. Metals which are considered hard are both solid and firm. They resist scratching or wear.

Many methods have been evolved for measuring hardness. Each has its particular features and all are frequently used. Some, like the file hardness test and the spark test, are necessarily used in shops which do not have the equipment to measure any of the properties except ductility. Others, like the Brinell and Rockwell hardness tests, are used in shops having the proper testing equipment.

The FILE HARDNESS test is the simplest of all, but not as accurate as machine tests. It can, however, be made pretty accurate if you know the temper of the file you're using. And when you don't have a manufacturer's standard assortment of files for hardness testing, you can temper your own files until you get them to any desired degree of hardness. Here's a table to use in tempering to attain certain hardnesses—

No temper	66 to 67	Rockwell "C" file hard
400° F. temper	61	Rockwell "C" file hard
500° F. temper	57.5	Rockwell "C" file hard

600° F. temper	54	Rockwell "C" file hard
660° F. temper	51	Rockwell "C" file hard
760° F. temper	47	Rockwell "C" file hard
825° F. temper	44	Rockwell "C" file hard
915° F. temper	40	Rockwell "C" file hard
975° F. temper	35	Rockwell "C" file hard
1,050° F. temper	26	Rockwell "C" file hard

You may use either Shore, Vickers, or Brinell readings just as well as the Rockwell "C" hardness values. The important thing is to find the SOFTEST file which will scratch the surface of the test metal.

A slightly different method is to use a new file to determine the resistance of the material to the cutting action of the file and from this make an estimate of the Brinell hardness number. Use a new machinist's hand file—temper approximately 500 degrees—and follow this table to determine what your findings indicate—

FILE HARDNESS TEST

BRINELL HARDNESS NUMBER (Approx.)	EASE WITH WHICH STEEL SURFACE CAN BE FILED[1]
100	File bites into surface very easily. Metal is very soft.
200	File readily removes metal with slightly more pressure. Metal is still quite soft.
300	At 300 Brinell, the metal exhibits its first real resistance to the file.
400	File removes metal with difficulty. Metal is quite hard.
500	File just barely removes metal. Metal is only slightly softer than file.
600	File slides over surface without removing metal. File teeth are dulled.

[1] Using a new, machinist's hand file.

Figure 64.—File hardness test.

In actual practice, you must depend on your skill and experience to get good results. You can file away certain metals by fast, light strokes, where slow, heavy strokes will produce little or no effect. Generally, the SLOWER you file the more accurate the test.

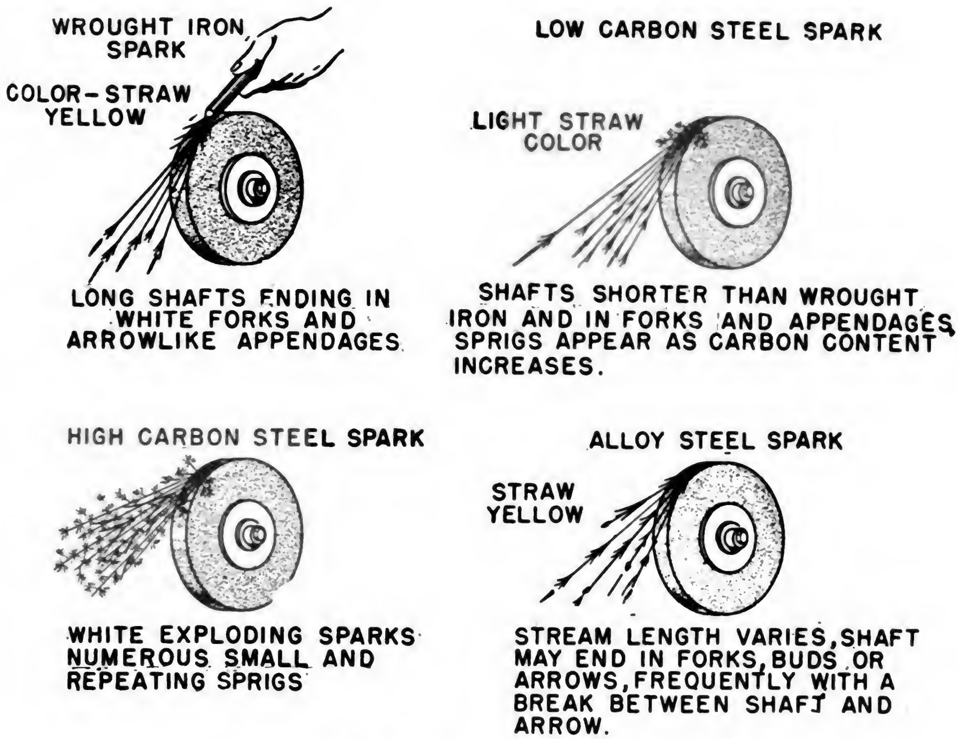

Figure 65.—Spark-testing ferrous metals.

Here's one more point to remember. The file testing method is less used on metals which have been changed by mechanical working or heat treatment than on normal metals. Steel, for instance, hardened by heat treatment, may resist filing immediately after quenching, but can be filed away quite easily after tempering. The file method may be used, though, to determine the hardness of welded parts.

SPARK TEST

The SPARK test, as you probably remember, is also used to determine the hardness of metal, particularly steel. Here's how it works. Hold a piece of steel lightly against the face of a grinding wheel and note the color and shape of the resulting sparks. The sparks from various forms of iron and steel vary

in length, shape, and color. Figure 65 shows four shapes of sparks.

The sparks from various low-carbon steels differ slightly. But they all have long white streaks that show some tendency to burst into white forked sparklers. Consult the chapter on identification of metals in M3c and 2c for more information on the sparks produced by other metals, if you don't already have the dope at hand or in your head.

BRINELL HARDNESS TESTING

The BRINELL hardness testing machine, figure 66, is designed so that a 10 mm. steel ball is pressed into the metal sample being tested. To make the test, first mount the sample in the machine, then bring the BALL PENETRATOR into contact with the

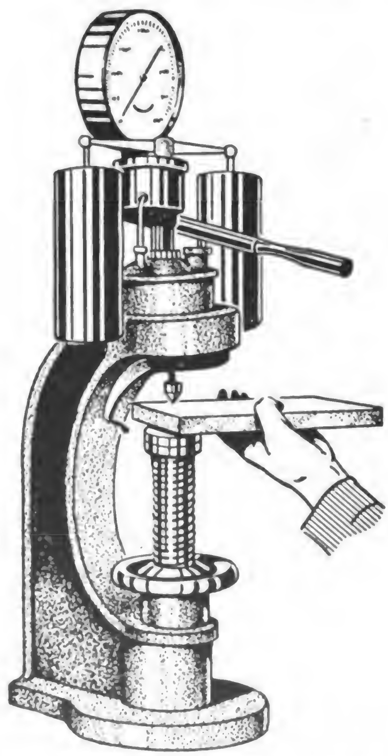

Figure 66.—Brinell hardness tester.

sample. Close the valve at the front of the machine, and operate the pump to bring the pressure to 300 kg. Open the valve to release the pressure. Read the diameter with the microscopic equipment provided, and check the Brinell Hardness Chart with your reading to find the Brinell Hardness Number.

If you know the Brinell Hardness Number you can estimate the tensile strength of the metal sample by following this formula—

$$\frac{\text{Brinell No.}}{2} \times 1000 = \text{Approx. Tensile Strength in psi.}$$

A BRINELL METER is a simple instrument which determines hardness by comparing the hardness of the sample with the hardness of standard blocks of metal on which the known

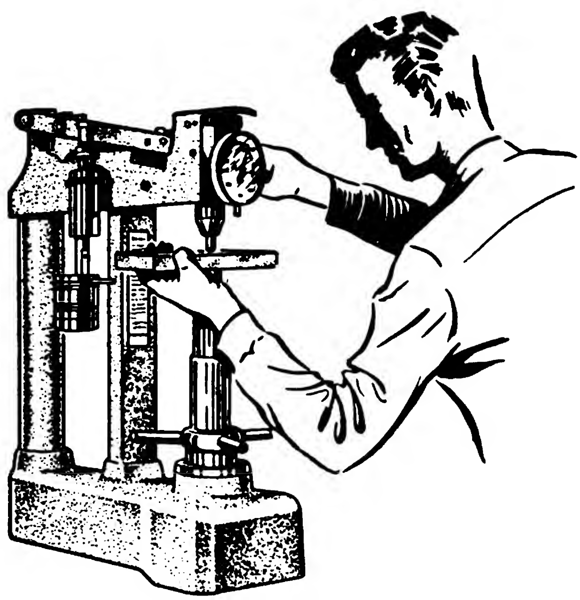

Figure 67.—Rockwell hardness tester.

Brinell Numbers are stamped. To use the meter, select the standard block whose hardness you believe most nearly matches the hardness of the sample. Mount the block in the meter. Place the meter over a smooth portion of the sample. Strike the plunger. As equal force is exerted by the plunger on both standard block and sample, a close estimate of the hardness of the sample can be made by comparing the two indentation marks. If there is considerable difference in the indentations, select another block and repeat the test.

ROCKWELL HARDNESS TEST

The indentation principle of the ROCKWELL test is similar to that of the Brinell but the Rockwell machine (figure 67) provides a direct reading of the hardness number. The Rockwell

penetrator is a 1/16 inch steel ball for soft metals and a diamond cone penetrator for the harder metals and alloys.

To make the Rockwell Test, first mount the diamond cone penetrator in the machine, and then arrange a 150 kg. load—see the weight rack at the back of the machine. Apply the load until the small arrow on the dial points to the red dot. This causes the penetrator to contact and grip the sample. Now set the outside dial to zero, and apply the full 150 kg. load by releasing the weights. Read the BLACK scale to get the Rockwell "C" hardness number of the steel.

For testing softer metals, use the steel ball with the 100 kg. load and read the RED scale to obtain the Rockwell "B" hardness number.

SCLEROSCOPE HARDNESS TEST

The SHORE SCLEROSCOPE (figure 68) measures hardness by the height of the rebound that a small diamond-tipped hammer

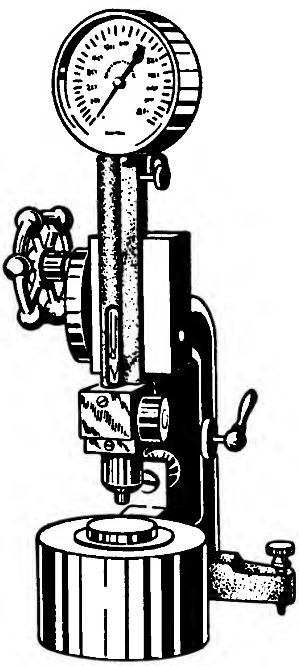

Figure 68.—The Shore scleroscope.

makes when dropped from a given height upon a specimen. The HARDER the MATERIAL, the GREATER the REBOUND. This is a quick and easy method of checking hardness, but your specimens must have a very smooth surface if you are to secure accurate results.

There are other tests for hardness, but those discussed are used most frequently. The machines for making them will be found on some repair ships and at major repair bases. You will learn the TECHNIQUE of the various types of machines only BY OPERATING THEM.

Since each hardness test differs considerably from most of the others, the results of one type cannot be converted accurately to another. For practical purposes, however, you'll find a conversion table in most standard metallurgy books. And remember—you are not required to pass tests on the use of hardness testing machines unless such equipment is provided for your use.

METHODS OF INSPECTION

Not every welded part must be destroyed to determine the quality of workmanship obtained. There are a number of NON-DESTRUCTIVE tests, only they're not called tests, but METHODS OF INSPECTION. Both terms are correct.

The most frequent method of inspection is VISUAL EXAMINATION. Obviously, only general defects and characteristics may be seen without the aid of instruments. Experience comes in handy here, as you must know what defects to look for and how serious they are, once you've found them. But you sometimes need something more than 20/20 eyes to detect poor workmanship in metal-working. What will you use? Three relatively quick and accurate non-destructive tests offer themselves—X-RAY, MAGNETIC, and MICROSCOPIC INSPECTION.

When non-destructive testing is required, the methods to be used and the locations to be examined will be specified on the plans or in the specifications for that job.

WELDING SPECIFICATIONS

The Navy has a series of codes, standards, and specifications for use on welding jobs. These specifications are usually published by BuShips and are available to all welding shops both afloat and ashore. Practically all of them specify what to do in different cases and are, therefore, the best information available on welding specifications. Study these specifications. You need to know them. Information on what tests to use is generally discussed in these bulletins.

Here's a list of the most frequently used BuShips publications you may need. They'll usually be held by the first lieutenant.

GENERAL SPECIFICATIONS FOR INSPECTION OF MATERIAL

Appendix VII, Welding

Part A, Section A-1, Nomenclature and Definitions.

Part A, Section A-2, Symbols.

Part B, Section B-1, Design of Arc and Gas Welded Joints.

Part C, Section C-3, Welding of Cast Steel.

Part C, Section C-9, Welding of Aluminum Base Alloys.

Part C, Section C-11, Silver Brazing of Ferrous and Non-ferrous Alloys.

Part D, Section D-1, Qualification of Welding Processes—General.

Part E, Section E-1, Qualification Tests for Metal Arc Welders.

Part E, Section E-2, Qualification Tests for Gas Welders.

Part E, Section E-5, Qualification Tests for Silver Brazing Operations.

Part F, Section F-1, Fabrication Tests for Resistance Welding.

Part G, Section G-1, Qualification of Equipment—General.

Part G, Section G-2, Qualification of Resistance Welding Equipment.

Appendix II, Metals

Part F, Section F-1, Definitions and Radiographic Requirements.

Part F, Section F-2, Radiographic Symbols.

GENERAL SPECIFICATION FOR THE BUILDING OF VESSELS FOR THE U. S. NAVY

Appendix 5, Specification for Welding.

Part I—General

Part II—Special Steels (Restricted).

GENERAL SPECIFICATIONS FOR MACHINERY
SI-4, Welding and Brazing.

Familiarize yourself with those publications and learn how to use them. They are additional tools of your trade which should solve most of your metal testing problems.

CHAPTER 9

DAMAGE CONTROL ORGANIZATION AND TRAINING

AROUND THE CLOCK

Damage control personnel are on the job ALL THE TIME. Those members of the ship's company who are designated as members of damage repair parties are the same men whose day-to-day job is routine maintenance of the ship's hull and operating machinery. Those men — Metalsmiths, shipfitters, carpenter's mates, electrician's mates, painters, machinist's mates, water-tenders, and others—maintain the ship so that it is always READY to do battle with the enemy or with the elements.

The Metalsmith is important in damage control because his regular work qualifies him as a good man to have around when repairs must be made to metal structures. This is particularly true when the job calls for gas and arc welding and cutting.

The DAMAGE CONTROL ORGANIZATION in which the metalsmith will work is set up for the type and class of ship involved. No standard organization would fit all ships. You can expect a different organization on each ship to which you may be assigned. Many factors influence the actual organization plans—structural changes, armament changes, type of operation and available personnel.

Changes are often made in organization as a result of the

transfer of key personnel, observed drills and exercises, scientific research, changes in complement, and the battle experiences of your ship and other fighting ships.

But, though damage control organization will vary from ship to ship, the objective remains the same—KEEP THE SHIP AFLOAT AND MANEUVERABLE WITH ALL ARMAMENT AND EQUIPMENT OPERATING AT MAXIMUM EFFICIENCY.

KNOW YOUR OWN SHIP

You—or one of your men—won't be able to get to Compartment B-216-L in a hurry if you don't know WHERE IT IS. It's an essential of damage control that you KNOW YOUR SHIP. As a leading petty officer you'll no doubt be responsible for training a repair party so well that each man knows the EXACT LOCATION of every fitting and every compartment of the ship. And EACH man must know the WHOLE SHIP—not just one section.

The reason for this is that ANY MEMBER of a repair party may be sent ANYWHERE on the ship to do damage control work. If one repair party is put out of action, another must take over. Another may mean ANY repair party, depending on the orders of the Damage Control Officer or the officer-in-charge of your own party.

Plans of the ship will be available for study. Many men have difficulty learning how to read these plans. It's up to you to help them. Be patient in your teaching and aid each man as much as you can. Have plenty of study material—plans and books—AVAILABLE—it won't do your men much good if it's locked up and not on hand for use.

During drills and exercises, and during regular instruction periods, train your men to learn their way around. You can give them blindfold tests to check their ability in finding their way about under adverse conditions. While every man should have a flashlight and use it WHEN SECURITY PERMITS, there will be many times when he'll have to move around without any light.

Sailors get tired of constant drilling, especially when it is monotonous. Vary the drills and liven them up as much as you can. In other words, PLAN YOUR TRAINING so it will be interesting. If your men are interested, they'll learn fast and well.

Teach your men to have CONFIDENCE in their ship. Explain its construction features, the numbering system for compartments and fittings, condition markings and the casualty power

system. Teach them all you can about fire pumps, drainage, the fire main, eductors, watertight closures, and so forth. Your men must know HOW to operate and maintain all the fittings provided for keeping the ship's compartments WATERTIGHT.

DAMAGE CONTROL COMMAND

The damage control organization of a ship is headed by the DAMAGE CONTROL OFFICER, who is normally the First Lieutenant. Large carriers and battleships may have a specially designated damage control officer. His will be an entirely separate authority, but nevertheless he'll be constantly working with the first lieutenant.

Figure 69.—Teach your men to "know the ship".

The DCO is responsible for—

COORDINATING the efforts of ALL DEPARTMENTS in the ship for damage control;

Placing the ship in the proper MATERIAL CONDITION for battle—this includes the maintenance AT ALL TIMES of the material and equipment used to preserve WATERTIGHT INTEGRITY;

REPAIRING DAMAGE during and after battle;

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. Supervising EXERCISES and TRAINING in damage control work.

The DCO has one or more assistants in addition to the officers and petty officer who are heads of REPAIR PARTIES. On smaller ships it's not unusual for a MIC to be in charge of a repair party. Or you, as a rated Metalsmith, may be an assistant to the man in charge of your party. In that case, you must know his duties in addition to your own.

The chain of command for a typical damage control organization is illustrated in figure 70.

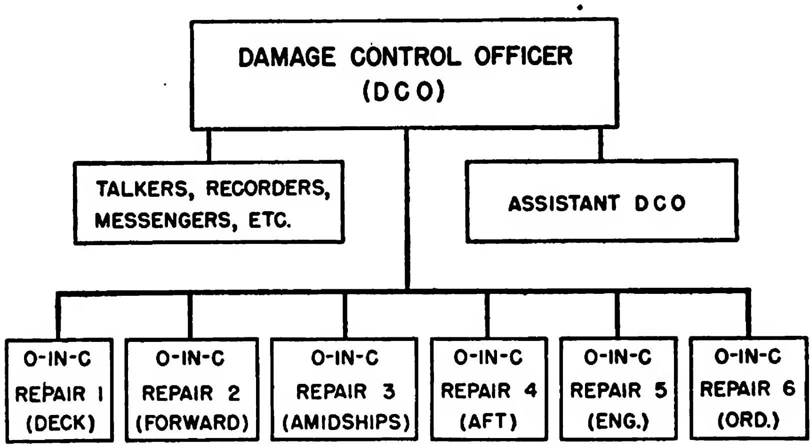


Figure 70.—Command for damage control.

The DCO, located in Damage Control CENTRAL STATION during GQ, is in constant communication with the bridge, control engine room, battle dressing stations, and ALL REPAIR PARTIES. This station is the HEART of the damage control organization. It's the clearing house for all information which concerns the condition of the ship. Orders concerning all damage control activities originate here.

REPAIR PARTY ORGANIZATION

For damage control work, the R division is supplemented by men from other divisions. Electrician's mates are assigned to operate switches and other controls, put in jumpers and hook up casualty power systems. Storekeepers must open storerooms in case of necessity, and MM's handle pumps and other machinery. And an "oil king" will be provided to handle valves and other fittings in the fuel oil and salt water piping systems.

Other men will be assigned to the party—to provide patrols,

fire-fighters and details for shoring, for wreckage removal, repair, and decontamination—as telephone talkers and messengers.

Skilled Metalsmiths, shipfitters and carpenter's mates will, in turn, be sent to other parties. Each party is organized, in other words, so it will have some experts in all phases of damage control work. It's a good practical example of not keeping all your eggs in one basket.

The repair party organization chart in figure 71 gives a general idea of the organization. It can't be more detailed because much of this information is CONFIDENTIAL.

Each repair party is assigned to ONE SECTION of the ship. A section, for damage control purposes, is a designated portion of the ship which is bounded fore and aft by watertight bulkheads and extends upward from the keel to the uppermost deck.

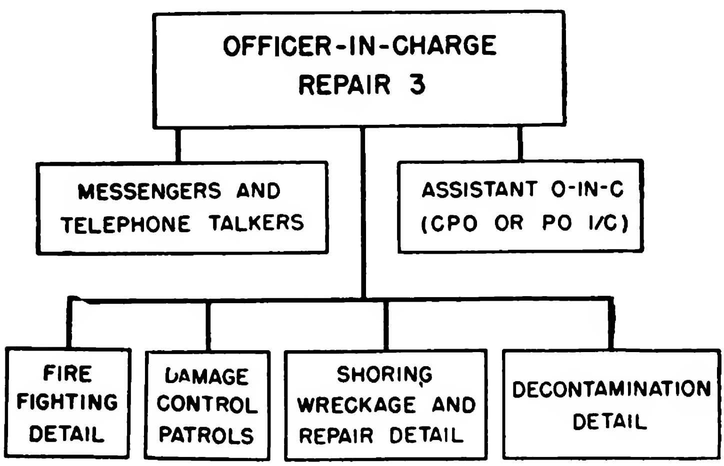


Figure 71.—Repair party organization.

Each section is further divided by compartments for efficiency in inspection and patrolling.

REPAIR PARTY STATIONS

The repair party station is headquarters for the party at GQ and for most drills. While a ship is cruising during war time one repair party station is ALWAYS FULLY MANNED.

A station is located in convenient and accessible space, and supplied with its share of the ship's emergency repair equipment. Each repair locker or space is arranged in the SAME WAY and as near the station as possible. If your ship is large, you

will have a fairly large compartment as your station. If you're on a small ship, your station may be merely the immediate vicinity of a repair locker.

The headquarters—station—of each repair party is in constant communication with Damage Control Central Station and with ALL OTHER repair party stations. In case one repair station is knocked out, personnel and equipment from other stations can be immediately dispatched to the scene of the damage.

REPAIR PARTY ACTION

Few of the men in a repair party remain at the repair station or locker. At GQ, all hands in the repair party turn to and set the WT fittings to the designated material condition. Each man is assigned to do a definite series of jobs in a specified area. A messenger, for example, might open and secure fittings near his station.

As soon as the material condition is established — AND CHECKED—the patrols assume their duties in assigned compartments. The firefighting, shoring, wreckage, repair, and decontamination details stand by at their assigned posts, check their equipment, and await action.

It is during this period of waiting that you, and other leading petty officers, can get in a lot of effective instruction work. During that time your men can become familiar with that area of the ship, its installations and fittings, and the emergency equipment provided for their use.

Men assigned to damage control PATROLS keep the O-in-C of their party informed of their activities and fittings by telephone reports. A LOG is kept of all pertinent information received at the repair party station. The information is also relayed to Damage Control Central, where it is again logged.

Men on patrol are not allowed to open WT doors, hatches or other fittings supposed to be closed during the set material condition without permission of the O-in-C of the repair party. The O-in-C, in turn, may be required to obtain permission of the Damage Control Officer. When permission is obtained to open a fitting, it is opened, then closed again AS SOON AS POSSIBLE, and IMMEDIATELY reported secure to the permitting authority.

If the size of the repair party allows, two men will go on patrol together. Otherwise each man patrols his beat alone. The first thing a man on patrol does is to establish communications with his repair party station.

DAMAGE CONTROL COMMUNICATIONS

The Damage Control Officer must be QUICKLY and ACCURATELY informed of the location, type and extent of ANY DAMAGE that has been sustained. The DCO, or one of his assistants, analyzes the information received and issues orders concerning corrective measures to be taken to minimize the damage.

The BATTLE TELEPHONE CIRCUITS—sound powered phones—form the backbone of the communication system for damage control. The JZ circuits are the primary network of this damage control system. If they fail, other circuits or other methods of communication are tried. If all installed equipment is OUT, a messenger is sent. Most ships, however, carry emergency 'phone sets that can be quickly rigged up over distances of 300 feet.

Make sure your men—all of them—know correct telephone talking procedure and have learned the standard phrases used by all ships. TELEPHONE TALKING is covered in the Training course for Non-rated Men and there's also a telephone talker's manual available.

The DCO will set up a list of the items of information he wants and the order in which they should be given. In the event of damage a man on patrol will identify his position—section of the ship—by stating his Repair Party. He will follow this with a statement of damage and an estimate of the extent of the damage.

Patrols and stations listening in might hear a report worded like this—REPAIR 3, COMPARTMENT A-308-A, SHELL HIT OR BOMB EXPLOSION IN COMPARTMENT B-302-E, BULKHEAD IN COMPARTMENT A-308-A RUPTURED, WILL INVESTIGATE DAMAGE.

The above report will be heard at Damage Control Central, repair party stations and by listening patrols. The O-in-C of Repair 3 will start men toward Compartment A-308-A IMMEDIATELY. The O-in-C of Repair 4 will, at the same time, be sending men toward Compartment B-302-E. The DCO will dispatch additional men from other parties if he thinks they are needed.

As soon as a man on patrol makes his initial damage report, he will continue his investigation and also inspect surrounding spaces for further damage. He will report any additional damage IMMEDIATELY. In addition he will furnish any in-

formation requested by his O-in-C or the DCO, such as the volume of water entering a compartment per minute, the depth of water, the number of submersible pumps in use, and so forth.

The DCO wants to KNOW WHAT'S GOING ON. He wants ALL THE INFORMATION he can get and he wants it IN A HURRY. Remember, he can't do a good job of damage control and save the ship unless he has all the information at his fingertips. So train your men to REPORT ANYTHING THAT MIGHT POSSIBLY BE OF HELP to the DCO and the repair parties.

WHAT TO REPORT

Train your men to keep their eyes open for any damage or trouble—particularly leakage—at all times. When any trouble is found AT ANY TIME, or in any part of the ship, it should be IMMEDIATELY REPORTED to the DCO. Here are some of the things to watch for.

First of all, there are the BIG things. For instance, fittings IMPROPERLY opened or closed for the material condition that's been set. Or OPENED SEAMS—either welded, riveted or caulked. Or SPRUNG doors, hatches, bulkheads, decks or piping.

Then there are the LITTLE things—harder to see, but just as quick to cause trouble. Look for damaged—or dirty—GASKETS on the WT doors, hatches, scuttles and ports—and for paint on the gaskets. Watch out for LEAKY pipe joints, fittings and valves—or for LOOSE dogs, hatch fittings, manhole cover bolts, and loose wiring connections or damaged insulation.

Loose or missing screws in VENTILATION clean-out plates are trouble causers, as are HOLES in ventilation ducts. So are bent or cracked PIPE BRACKETS.

Then there are the MISSING things—sounding tubes, for instance, or missing or illegible identification markings, and missing or damaged repair locker tools. And if FIRE FIGHTING equipment is missing—or in poor condition—you are in for trouble.

Also keep an eye open for STUFFING TUBES which are improperly packed or welded. Check to be sure that emergency HAND LAMPS and POWER EQUIPMENT is ready for use—and that equipment manuals, charts, and pamphlets are in place in the damage control locker.

Lastly, watch out for CARELESSNESS on the part of your men

—particularly in opening, closing, and securing WT fittings.

Watertight integrity aboard ship is everybody's responsibility. Anything that any man discovers that will hurt watertight integrity—a weeping rivet, a loose dog or a ripped gasket—should be REPORTED TO THE DAMAGE CONTROL OFFICER IMMEDIATELY.

TEN COMMANDMENTS OF DAMAGE CONTROL

Here are the ten commandments of Damage Control. Use them as a guide for yourself and to teach your men the importance of this work—

1. Do all you can to keep your ship WATERTIGHT.
2. Do not violate material conditions.
3. Have CONFIDENCE in your ship.
4. Know your way around the ship—even in the dark.
5. Know how to USE and MAINTAIN your damage control gear.
6. Report all damage IMMEDIATELY.
7. Keep personal gear secured.
8. Practice personal damage control by following all the rules.
9. Take every possible action to SAVE YOUR SHIP as long as a bit of hope remains.
10. Always keep COOL, use your HEAD and—
    DON'T GIVE UP THE SHIP!

CHAPTER 10

EMERGENCY DAMAGE REPAIR

ONE GOT THROUGH

Pretend—for a moment—you're back in the days of World War II. Your ship is in a task force operating off Blank Island. And—Here they come! Three suicide planes—enemy expendables. But you can't see them. You're below at REPAIR IV—petty officer in charge of that station. You're ready for anything but you have little to do until—

Ninety percent of your work was done BEFORE the call of the gong sent you to battle station. Metalsmiths, shipfitters, and carpenter's mates have been plenty busy checking, testing, overhauling, tightening, adjusting and rechecking watertight fittings. You haven't overlooked your firefighting gear either—nor damage control equipment. It's all in tiptop shape—100% ready for action.

Are those planes still coming? You watch the talker—you strain your ears—waiting for information. Suddenly you hear the 40's join the 5-inchers. Almost immediately the talker signals that two planes are down. But you know the last one is still coming because now you hear the muffled chatter of the 20's.

You know this is it and you tighten up. You should be too scared to think but surprisingly you're not. You wonder what

equipment you'll need, whether you'll have to use casualty power for the submersible pumps, whether the handy billy engine will start with the first pull, whether you have enough shores.

Your thoughts are interrupted by the shudder of the ship and the WHAM of the explosion as the plane hits. You guess the hit is on the port quarter. You wait for orders but not for long. The DCO calls four of your crew to REPAIR III to replace men wiped out instantly by the explosion. The fight against fire and flood has begun.

Only a minute before the repair parties were just waiting, standing by and feeling unimportant and useless. Now they're carrying the load. The skill and training that you and other petty officers have drummed into your crews may be the deciding factor in saving the ship and hundreds of lives.

Your ship plows on. Luckily there was no serious damage to steering or propulsion gear. Fire is raging in the damaged area but it's coming under control. You're ordered to the scene of the damage to stand by with repair equipment and supplies—to make emergency repairs when the fire is out.

REPAIR III sends a man down to survey the damage. He reports a huge hole just above the waterline and evidence of a number of smaller holes below the waterline. Seams have opened, cracks have appeared, piping is twisted and ruptured, and watertight doors and hatches are warped. Considerable water is coming in but flooding boundaries have been set and are being maintained.

Minutes ago the damaged sections of piping were cut out by men—your men—who knew their piping lines and valves. Fire main jumpers have supplied plenty of water and the fire is going out.

The Captain wants repairs made as soon as possible. He knows the ship is not fatally damaged and that it's still an effective fighting unit. But he also knows that, with the ship damaged, another suicide plane hit—or some rough weather—might be fatal.

FIRE FIGHTING

But before repairs can be made, the FIRES must be put out. FIRE FIGHTING is a part of the job of almost every man aboard, but particularly of those engaged directly in damage control.

It's not discussed in this book for it's adequately covered in other publications, especially *Fire Fighting Manual (NAVSHIPS 688).* Get hold of a copy of the latest edition of this book—it's reprinted from time to time to cover the latest fire fighting equipment and newest techniques. Study it—KNOW IT.

IT'S YOUR RESPONSIBILTY

Now for the REPAIRS. Repairing a seriously damaged ship so that she can stay afloat and fight effectively is not a job to

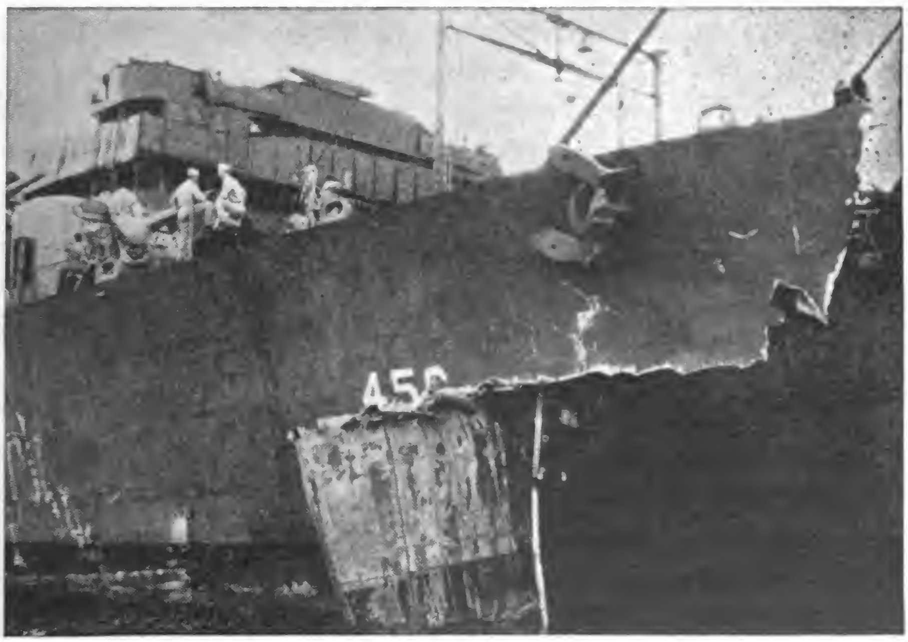


Figure 72.—Damaged bow of the O'Bannon.

be entrusted to novices. You and your men have got to KNOW YOUR STUFF. You've got to go in quick with your repair gear —plugs, plate patches, sholes, shores, wedges, box patches and tools—and get those emergency repairs under way.

Many ships—the *Boise, Minneapolis, New Orleans, Honolulu,* just to mention a few—have been saved because their damage control and repair parties were able to make adequate emergency repairs in DOUBLE QUICK TIME. You've got to BE PREPARED. The men of the *O'Bannon* (figure 72) were certainly prepared when they saved their ship after the bow was smashed up.

So it's up to YOU, your men and the other artificers to minimize, limit, and repair damage. Like the regular work of your rate, it's KNOW-HOW, PRACTICE and TRAINING that pays off. This chapter provides a lot of the facts to help you get that all-important KNOW-HOW.

INVESTIGATING DAMAGE

First, the basic rule again—any damage to your ship must be REPORTED IMMEDIATELY to the DCO. If he's informed of all damages and their extent, he can intelligently shift damage control personnel and assign priorities to repair jobs.

Here are some of the things he wants to know—the KIND and SIZE of PROJECTILE causing the damage, the EXACT LOCATION of the hit, whether the explosion occurred INSIDE or OUTSIDE of the damaged compartment, and the EXTENT of FLOODING, if any, plus an ESTIMATE of how many GALLONS of WATER are entering PER MINUTE. Lastly—are fires, if any, UNDER CONTROL?

You can't report the above information unless you make an investigation. Get the DCO's permission to pass through the watertight door or hatch. As soon as you've passed through the opening, secure it, then plug in your phone and report the opening secured to the DCO. This procedure must be repeated for each WT opening.

Now, here are some pointers about investigation procedure and precautions. Always wear RESCUE BREATHING apparatus, work in PAIRS and use a LIFELINE. Establish COMMUNICATIONS immediately. Remove CASUALTIES, at once, then wreckage and contaminated water. Secure air vents. Keep a damage LOG to expedite repairs.

And, of course, never open WT fittings until you test for FLOODING. Compartments can be tested for flooding by removing sounding caps and air test fitting caps. Remove the cap SLOWLY and REPLACE IT after the test.

While damage will usually be greatest in the immediate area of the hit, there may aso be serious damage in compartments at a considerable distance. All areas that could possibly be damaged must be investigated and ALL DAMAGE—however small—must be LOGGED and REPORTED to the DCO. Check for damage to piping, ventilation ducts and fittings, cable stuffing tubes, WT closures and boundary joints.

Keep close track of your men who are investigating damage or possible damage. Know WHERE they are and WHAT they are doing.

The DCO won't fool around when he gets reports. He'll immediately tell you what repair jobs to start. He may assign each member of the repair party to a certain job or he may leave the responsibility to an assistant DCO or to YOU.

HOLD WHAT YOU HAVE

As you investigate damage note what can be done to hold it to its ORIGINAL area. Do everything you can to prevent PROGRESSIVE flooding and burning. Ships have sunk because flooding and fire boundaries were not established when and where possible.

Repair men often waste valuable time trying to patch holes in compartments which are already flooded. They overlook holes which cause progressive flooding. Remember that there is little or nothing you can do IMMEDIATELY about compartments that are completely flooded.

Instead of wasting time on a flooded compartment, set up a FLOODING BOUNDARY. Locate and select those bulkheads and decks around the damaged area which you should be able to keep dry. Make sure that you can hold the boundary, post a watch on it at possible weak spots, then use it as a base for moving in against the damage.

Advance the flooding boundary nearer to the damage as fast as you can but DON'T LOSE THE ORIGINAL BOUNDARY. Patch first the holes through which the most water is coming.

Set a watch when temporary repairs—shoring, plugs, and so forth—have been installed. After the first investigation keep patrols busy looking for further damage or damage overlooked during the first quick examination.

FLOODING EFFECT OF HOLES

The volume of water coming through a hole depends on the SIZE—area—of the hole and its DEPTH—ordinarily the distance below the actual waterline.

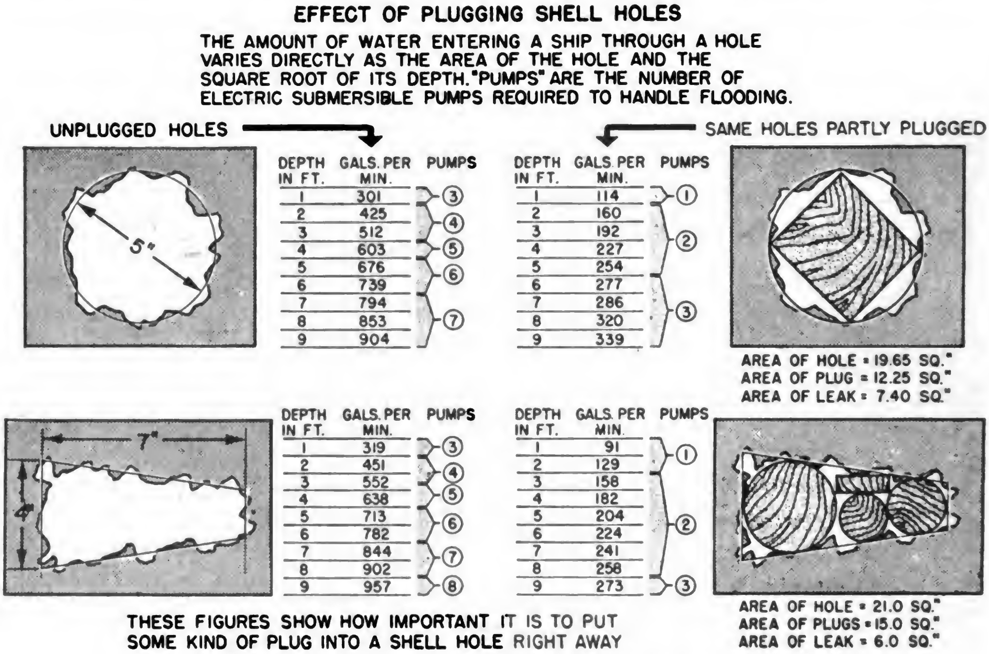
The flooding effects of UNPLUGGED holes are compared in figure 73, to the flooding effects of those PARTIALLY plugged. Comparisons are made in terms of gallons of water per minute

and submersibles required to handle the flooding.

That illustration emphasizes the importance of getting some kind of plug into the hole RIGHT AWAY. Any plug that will REDUCE THE AREA OF ENTRY will be valuable, for then some of the pumps can be released for other uses and possibly some repair personnel as well.

DON'T FORGET THE LITTLE HOLES

While investigating damage, you may find SMALL holes and leaks—caused by cracked plates, pulled seams, warped hatches



DEPTH IN FT.	GALS. PER MIN.	PUMPS
1	301	3
2	425	4
3	512	
4	603	5
5	676	6
6	739	
7	794	7
8	853	
9	904	

DEPTH IN FT.	GALS. PER MIN.	PUMPS
1	114	1
2	160	2
3	192	
4	227	
5	254	
6	277	
7	286	3
8	320	
9	339	

DEPTH IN FT.	GALS. PER MIN.	PUMPS
1	319	3
2	451	4
3	552	
4	638	5
5	713	6
6	782	
7	844	7
8	902	
9	957	8

DEPTH IN FT.	GALS. PER MIN.	PUMPS
1	91	1
2	129	2
3	158	
4	182	
5	204	
6	224	
7	241	
8	258	
9	273	3

Figure 73.—Effect of plugging holes.

and doors, damaged stuffing tubes, or by shrapnel. You logged these leaks during the first investigation but left them until the more dangerous holes were plugged or patched. They should now be patched with prefabricated patches, plugs, boxes, bucket patches, oakum, or any other available material—even undershirts and rags.

These are temporary repairs, of course, but anything you can do to reduce the amount of water entering and spreading through the ship will give your pumps a better chance.

If one type of patch fails to stop a leak, try another. Remember—the important thing is to stop SOME of that water

from entering. GET SOMETHING INTO THE HOLE OR OVER IT. Even fifty percent stoppage of a leak is a big help.

Keep in mind that your goal is to MINIMIZE damage by LOCALIZING FLOODING and PRESERVING BUOYANCY. Then your ship can maneuver and be maintained as a LEVEL gun platform.

Emergency patches described in this chapter have all been used by repair parties of damaged ships. Many of them can be made up—prefabricated—and held in readiness. Many others can be made up in a short time after the damage. None are a difficult job for a good Metalsmith.

WOOD PLUGS

Conical, square-ended and wedge-shaped WOODEN plugs—plenty of them of assorted sizes and shapes—are standard

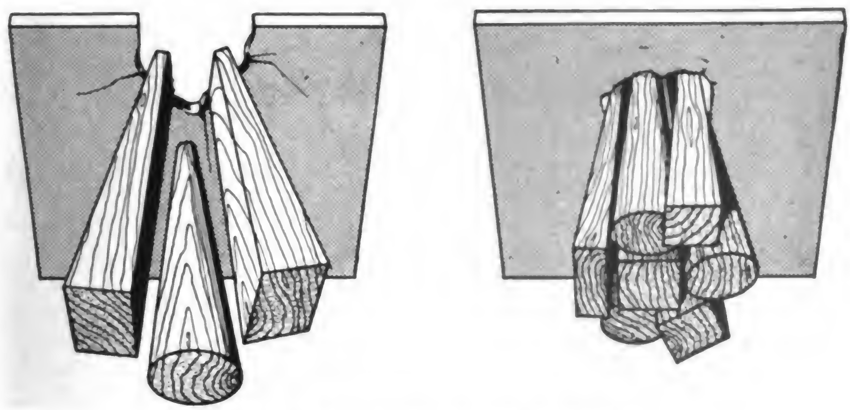


Figure 74.—Using wooden plugs.

repair locker equipment. The best plugs are made of SOFT wood and are left UNPAINTED. The safest plugs have been treated with a FIRE RESISTANT material.

Wooden plugs enable you to make quick and efficient repairs. They can be used from either side of a hole. Drive them with a MALLET or a WIDE FACED HAMMER to avoid splitting. If such tools are not available, just place a wooden block flat against the end of the wedge and pound against it. You may ruin the block but you'll keep the wedge from splitting.

Conical and square-ended plugs may be used to stop leaks in shattered bulkheads as pictured in figure 74. It's always good practice to place a CLOTH over the hole before driving the plug. Or you can wrap the cloth around the plug (figure 75).

Greater watertightness may be gained by driving smaller wedges or oakum into the unfilled spaces around plugs.

Plugging an underwater hole with wooden plugs is a difficult job because of inaccessibility and water pressure. It's also a dangerous job because if a flooded compartment is "unbuttoned", there is constant danger of progressive flooding and loss of the original flooding boundary.

Suppose you want to enter a flooded compartment or one you suspect is flooded. Naturally you can't just undog a door or hatch without careful investigation and the PERMISSION of the DCO. So try to get an estimate of the amount of water in the compartment by removing an air-test fitting cap. The pressure

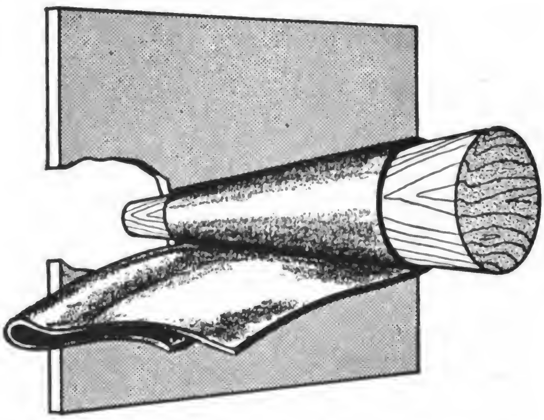


Figure 75.—Wrapping a plug with cloth.

of the water escaping through the fitting will be a good indication of the depth of water in the compartment.

CRACKS

Cracks may result from battle damage, collision, firing of heavy guns or steaming at high speeds through heavy seas. Wedging is not always desirable for cracks because wedges tend to spread and enlarge them. Try OAKUM or RAGS first. Drill a hole at EACH END of the crack to prevent it spreading and growing.

WELDING is the best repair for cracks, if conditions permit. However, DON'T try to repair a RIVETED seam by welding because the heat required will only enlarge the damage. Try CAULKING riveted joints if the leaks are small. Fall back on clamped or shored PATCHES if other methods fail.

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PATCHING LARGE HOLES

It's almost impossible for the ship's crew to repair LARGE UNDERWATER holes made by torpedoes or mines. Such work must be left for the drydock. But you may be able to patch

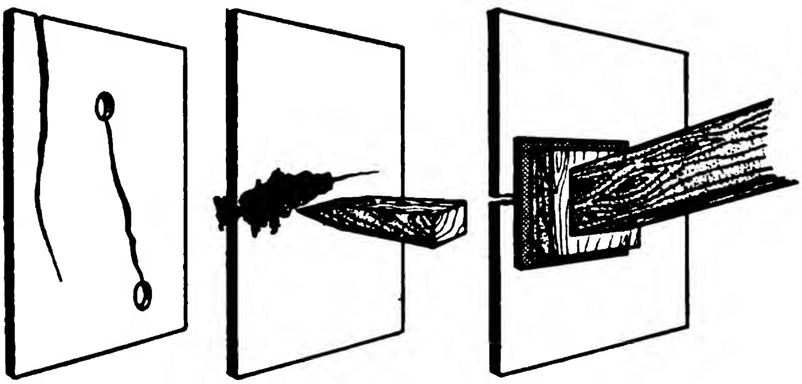


Figure 76.—Stop those crack leaks.

holes just below the waterline and you certainly can do something about those ABOVE the waterline.

Holes near or above the waterline can be just as dangerous as those well down on the hull. That's because any flood water coming in high usually has more FREE SURFACE over

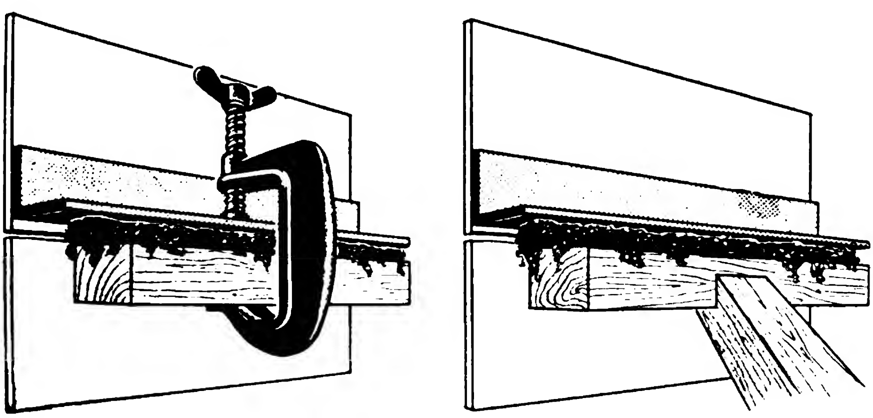


Figure 77.—Plugging leaky seams.

which it can surge back and forth, and thus seriously affect the ship's stability. Also, topside floodwater is a threat to buoyancy and raises the center of gravity, thereby increasing pitch and roll.

CONCRETE may be used for sealing stubborn SEAM LEAKS.

Build a wooden form alongside the seam on the unflooded side and fill it with mixed concrete.

How can you patch such holes? If they are not too large you may be able to roll up a PILLOW or a MATTRESS and shove it into the hole (figure 78). Such plugs are usually only temporary measures as they are difficult to keep in place. As soon as you can, try something more permanent, an OUTSIDE PATCH for example.

CLOTH PLUG PATCH

PROJECTILE holes in the hull may be patched or plugged quickly if the patch or plug is applied from the OUTSIDE. Repair from outside is necessary because the inside of the hole will have rough and jagged edges.

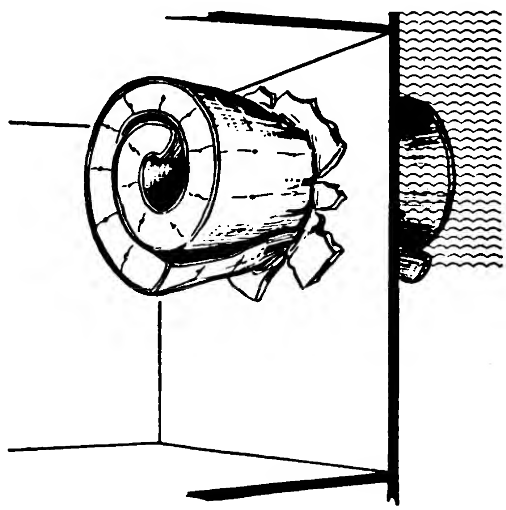


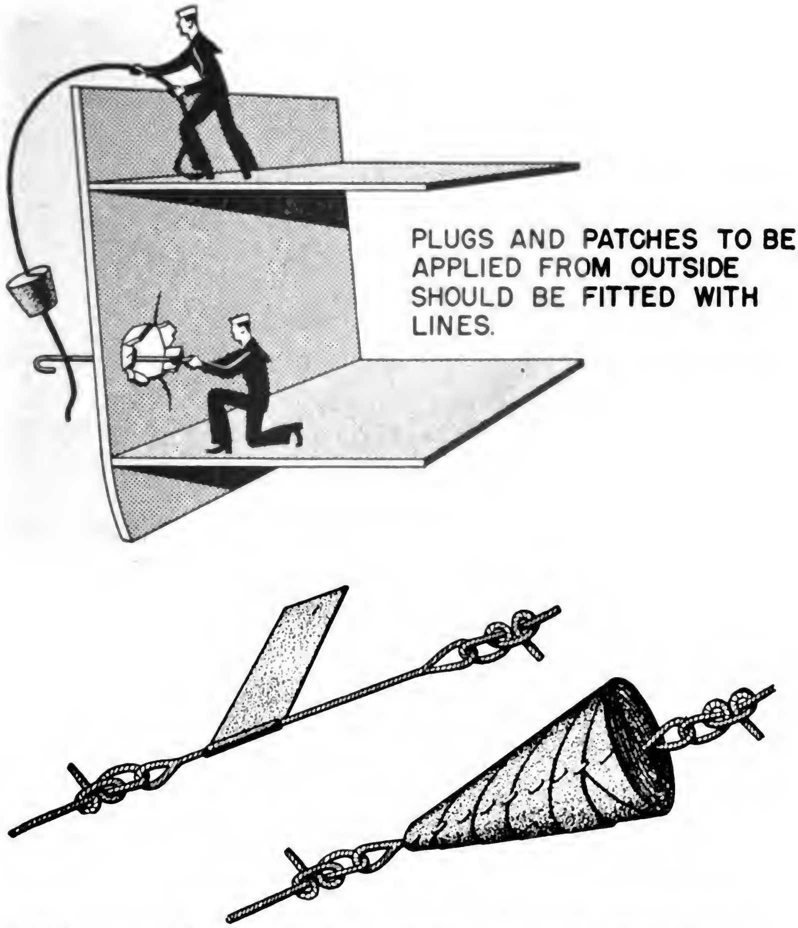
Figure 78.—Use anything to stuff a hole.

Figure 79 shows a CLOTH PLUG patch used by one repair party to plug a large hole near the waterline. Extensive wreckage inside the holed compartment prevented a satisfactory patch from being placed inside. Before this patch was applied four submersibles were required to handle the floodwater. This patch stopped the flow to the extent that only one pump was required.

Make the plug patch around a core of heavy line about three feet long. Splice an eye into each end of the core line, then wrap with strips of blanket until you have a cone of the required size. The layers of cloth must be stitched and served.

PLATE PATCH WITH GASKET

One of the most useful prefabricated patches is made of a square piece of ¼ inch PLATE. One face of the plate is gasketed near the edge with canvas stuffed with oakum, rubber, or other suitable gasketing material. Plate patches up to five feet square have been used with good results.



CONICAL PLUG MADE OF BLANKET STRIPS WRAPPED AROUND A LINE AND STITCHED

Figure 79.—A large cloth plug patch.

An EYEBOLT is welded to the center of the plate, on the gasketed surface, to which a line can be made fast for installing the patch and securing it from the inside. Large patches of this type require one or more PADEYES for handling and securing.

The plate patch is installed by lowering it over the side so

that the center line can be grabbed through the hole. After the patch is in place, and if it must hold for an extended time, permanent fastenings—welded and threaded—can be devised.

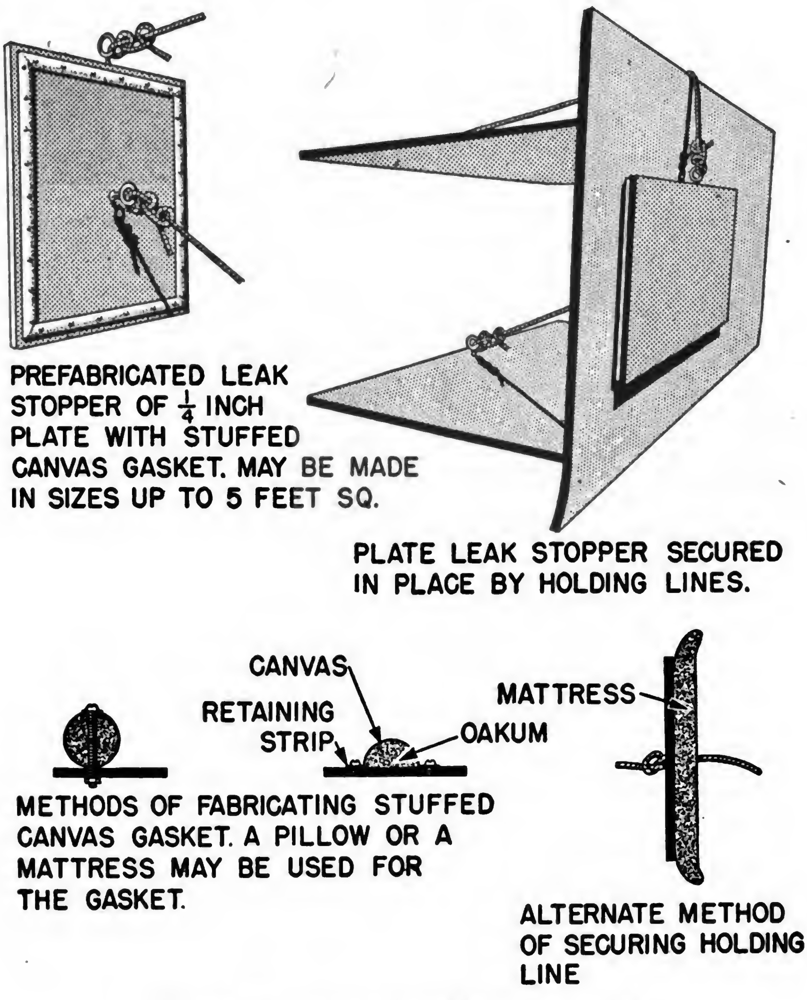


Figure 80.—Large outside plate patch.

A number of these patches, of assorted sizes, should be made up and ready. They are not difficult to construct and they take up very little storage space.

MATTRESS PATCH (OUTSIDE HULL)

If you do not have suitable prefabricated patches you can improvise an outside patch like that shown in figure 81. It's made of a crew MATTRESS and suitable backing, such as a mess table top. If a wooden backplate is used, securing lines are

run through bored holes. Eyebolts can be welded to plate backing for the same purpose.

BOLT PATCHES

FOLDING T-BOLT patches are designed for patching holes difficult to reach from the outside. This type of patch, shown in figure 82, can be completely installed from inside the hull. The illustration shows the construction of the T-bolt and various ways in which it can be used.

HOOK BOLTS, with shapes resembling the letters *J, L* and *T*, can be used to secure patches over holes as shown in figure 83. The same types of bolts can also be used with box patches.

FOLDING PLATE PATCH

Figure 84 shows how a circular FOLDING PLATE patch is constructed and installed. It's a patch that can be put on in a hurry. The two parts of one of these patches can be cut from ¼ inch plate. Weld or braze on the hinges, thread and knot the line and you have a good quick patch.

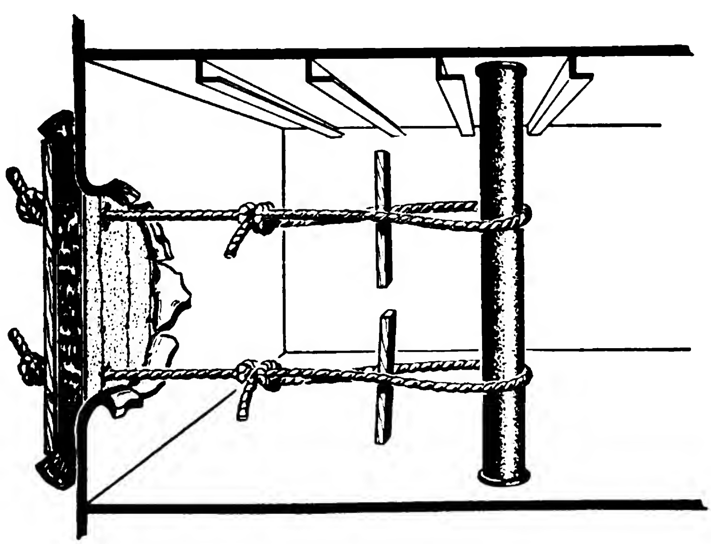


Figure 81.—Mattress patch for the hull (outside).

SHORED MATTRESS PATCH (INSIDE)

One of the fastest patches for medium and large holes is made by slapping a MATTRESS—preferably innerspring—over

the hole, backing it with suitable rigid material and then bracing it with shoring. One of these patches is shown in figure 85.

BOX PATCHES

Small and medium holes, especially those with jagged edges, may be stopped by the application of simple BOX patches. To

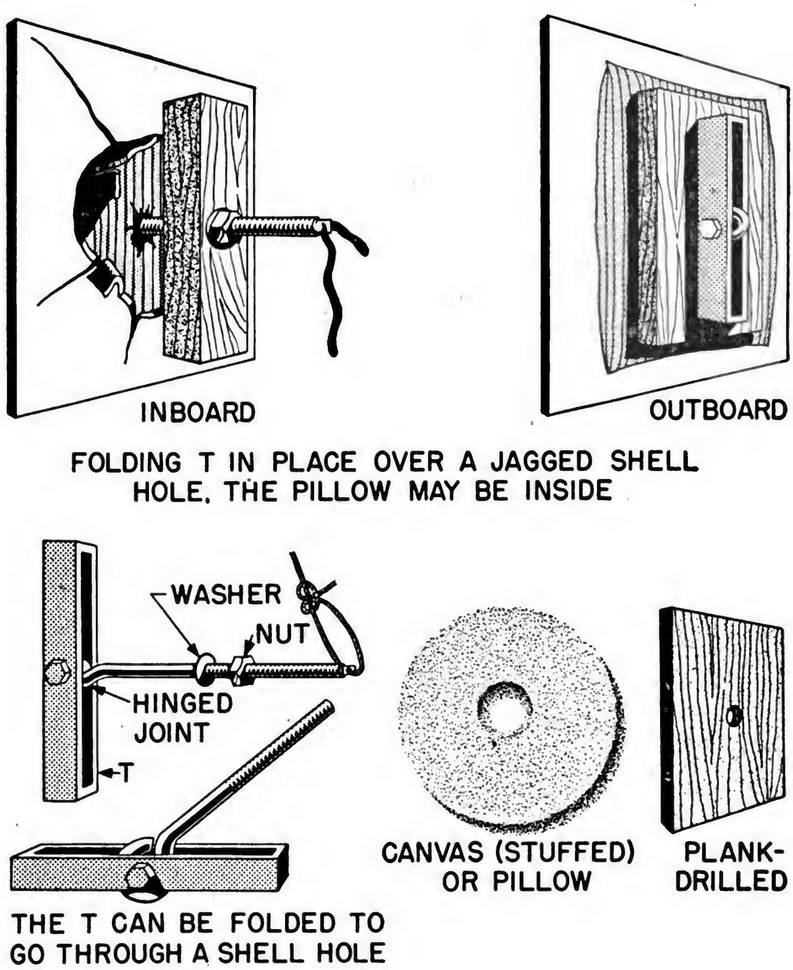


Figure 82.—Folding T-bolt patches.

make one of these patches just fit gasketing material along the edge of a steel or wooden box, similar to that in figure 86.

A WOODEN box is handy because its edges can be chopped off to fit the contour of the plating around the hole. It may be shored or secured with hook bolts. The disadvantage of wooden construction is that due to the fire hazard, a minimum

quantity of wood is carried by fighting ships.

METAL BOXES have the advantage of being FIREPROOF. Fur-

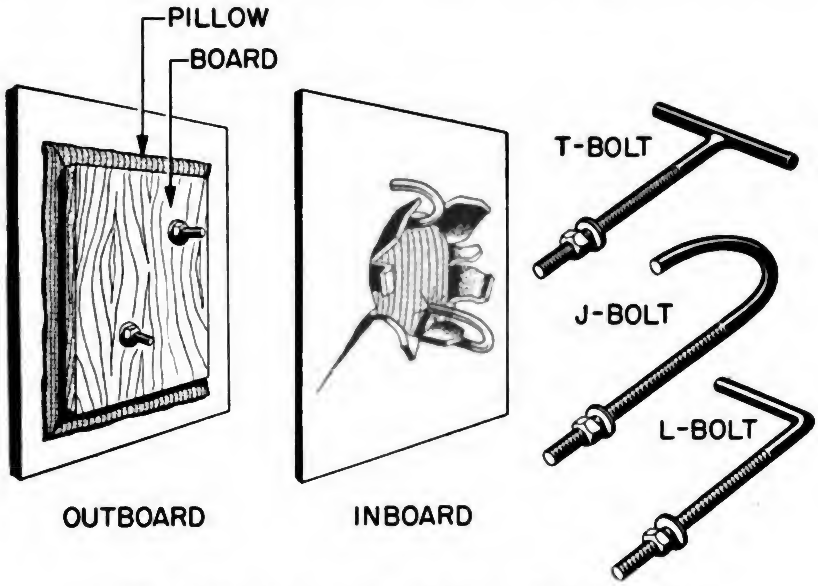


Figure 83.—Securing patches with hook bolts.

thermore, they can be more permanently installed because you can secure them with welded angle clips. Shore them at first

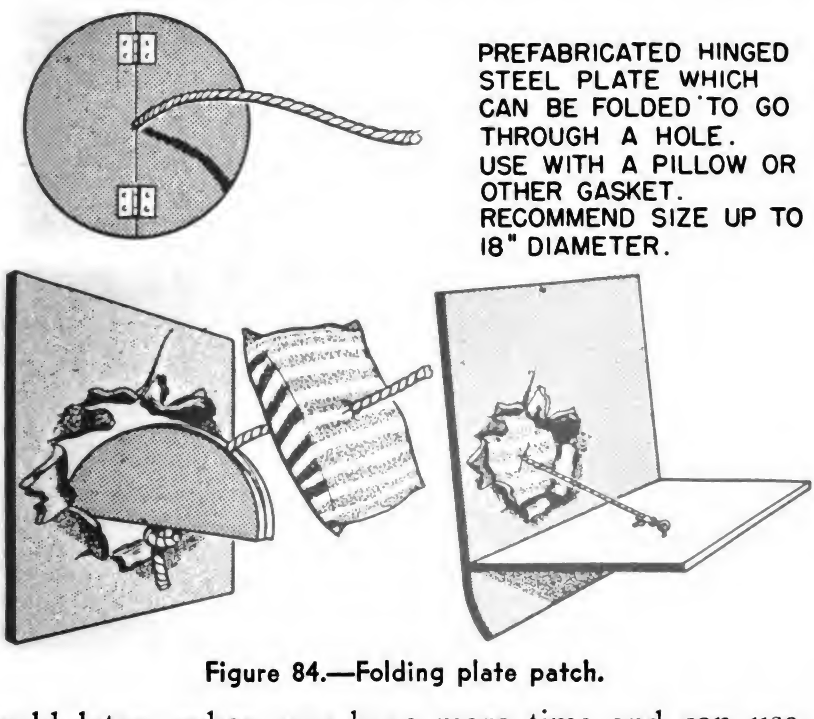


Figure 84.—Folding plate patch.

and weld later—when you have more time and can use your welding equipment with less danger of fire and explosion.

If a box patch does not fit snugly against the plating, try stopping the leaks with small wedges or oakum.

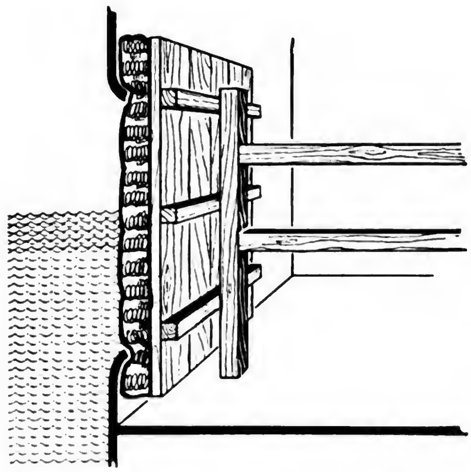


Figure 85.—Shored mattress patch.

COFFERDAMS

The boxes described above are really small COFFERDAMS. Cofferdams are comparatively large box-like structures which are specially built—tailor-made—to provide access to flooded

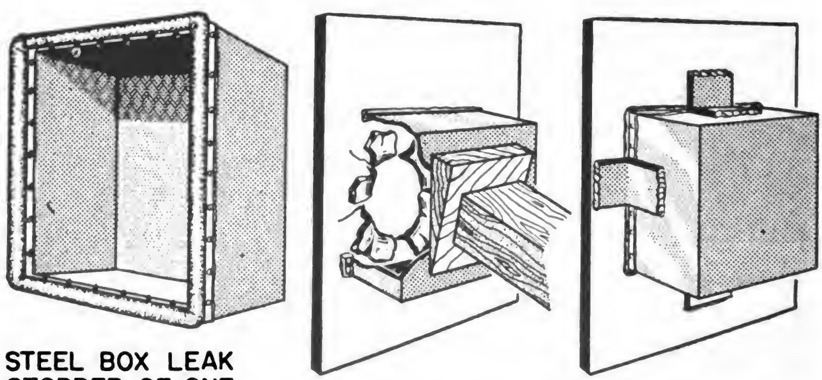


Figure 86.—Application of box patches.

compartments. Aboard ship they are made of steel plate or available lumber, and shored tightly against the opening around which they are built.

BUCKET patches can be made by gasketing the edge of a bucket, putting a hole in the bottom, and using the bucket as a box. Reinforce the bucket with a strong back and secure it with a hook bolt.

PIPE REPAIRS

When you have to repair or patch piping, remove the pressure before you begin. Adequate service can be maintained with jumpers or cross-connections.

SOFT PATCHES—temporary—can be used to stop leaks due to small holes or cracks in LOW PRESSURE lines including all water

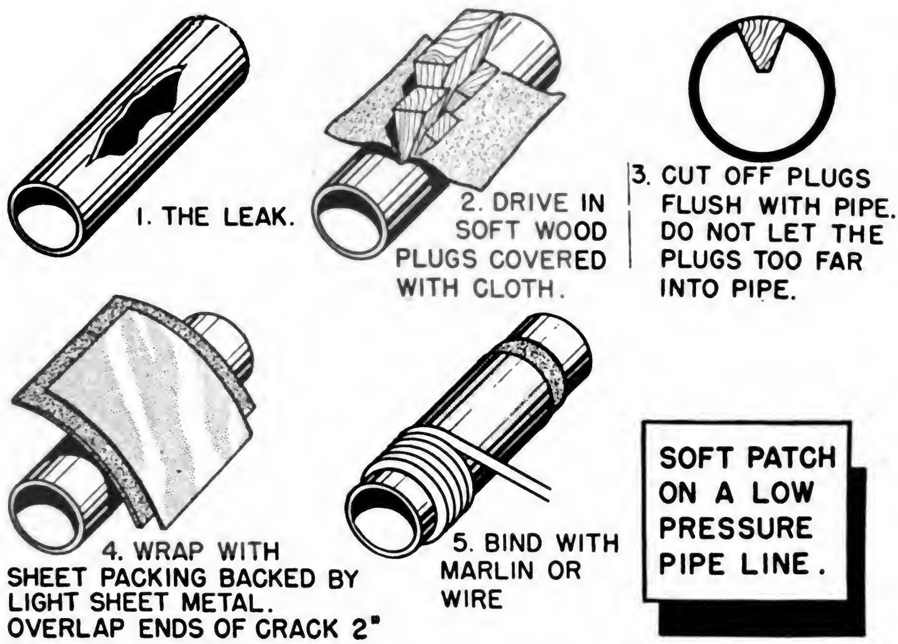


Figure 87.—Soft patch for low-pressure piping.

piping. First plug the opening with soft WOOD plugs and wedges. Avoid excessive wood inside the pipe as it will retard the flow and cut down capacity. Trim the plugs and wedges so they are flush with the outside of the pipe. Wrap rubber sheeting over the damaged area, back with light sheet metal, and bind with wire or marlin, as illustrated in figure 87.

Don't forget this—a PATCHED STEAM PIPE should not be subjected to MORE THAN 150 PSI PRESSURE.

HIGH-PRESSURE lines—steam—over 250 psi CANNOT be repaired satisfactorily with ANY KIND OF PATCH. These lines are made exceptionally strong and with a high safety factor. If

they crack, or are holed by shrapnel, everything else will probably be knocked out too.

Damaged GASOLINE lines must be REPLACED rather than patched. The slightest leak in a gasoline line creates a tremendous fire hazard.

JUBILEE PIPE PATCHES

JUBILEE patches (figure 88) can be fabricated by any Metalsmith. When you make up such a patch, just remember that the more pressure required to stop the leak, the more the patch

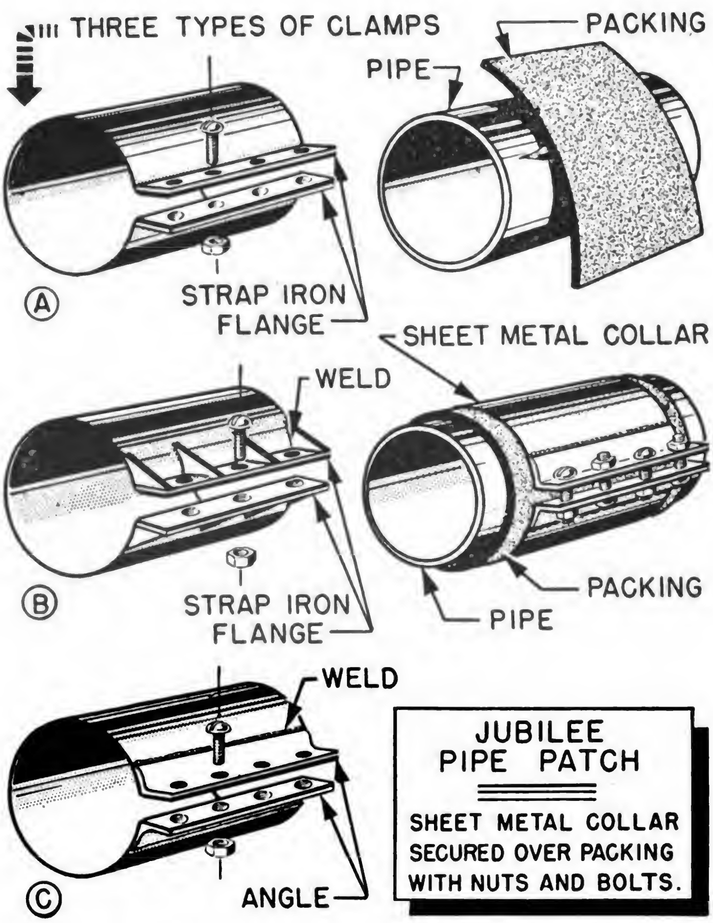


Figure 88.—Jubilee pipe patches.

flange must be reinforced. If you need one of these patches in a hurry, just form up the cylindrical part out of heavy sheet metal, bend the flanges, and then clamp them in place.

PIPE AND HOSE BANDING

Complete BANDING TOOL KITS—for double-wrap handling—are supplied for repair lockers. These kits can be used for emergency banding of piping patches and for routine repairs to such items as gas welding hose and arc welding cable terminals.

Full instructions for using the kits are supplied with them by the manufacturer. The banding material is usually 0.625 inch by 0.030 inch galvanized steel, furnished in rolls. The required length of banding is twice the pipe diameter plus 6

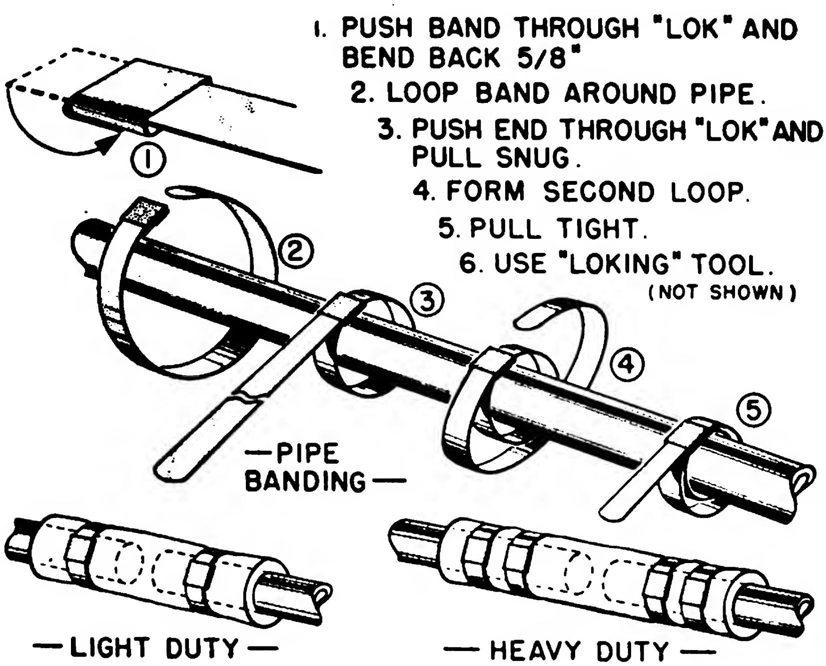


Figure 89.—Pipe banding.

inches. The band is assembled as shown in figure 89, then tightened, and locked with the patented "LOCKING" TOOL.

WELDED PLATE PATCHES

WELDED PATCHES are seldom put on during action due to danger from fire or explosion. Usually it's better to slap on a shored or bolted patch, or one secured with a line. Later, when damage is under control and working conditions safe, perhaps you can remove some of the quick temporary patches, straighten or cut away jagged edges, and weld more permanent patches in place.

Welding a plate over a hole involves the same procedure as other welding jobs. The plate is first tacked in place and then a bead is run all the way around the edges. If the welded plate is large, add some angle bars for stiffeners and then shore for still more strength and rigidity.

TEST THE AIR BEFORE WELDING

One of the greatest hazards aboard ship is IMPURE AIR. Even in normal ship operation the air may become contaminated with poisonous and explosive gases. This danger becomes much greater when the ship has been damaged.

In some spaces the air may not contain sufficient oxygen to keep a man alive. Always test the air when there's a possibility that it lacks oxygen or contains explosive gases.

Enter damaged spaces and others which may contain impure air only when wearing RESCUE BREATHING APPARATUS. Don't remove the breathing apparatus until you've tested the air and found it safe. Even then, keep the apparatus ready for use.

Open FLAMES and SPARKS must be religiously avoided in any spaces or compartments suspected of containing explosive gases. Only approved methods and equipment should be used for testing the air.

If any arc welding or gas welding or cutting must be done to effect repairs, you must check NOT ONLY the space or compartment involved BUT ALSO ALL ADJOINING spaces and compartments.

FLAME SAFETY LAMP

THE FLAME SAFETY LAMP, figure 90, is often used to test for OXYGEN SUFFICIENCY or EXPLOSIVE GASES in compartments, spaces and voids which are normally kept closed but must be opened for inspection, repair, cleaning or painting. The flame of the lamp indicates by its action the presence or absence of sufficient oxygen to support life. In addition, the flame is affected by explosive gases.

If the action of the flame indicates that there are explosive gases the lamp should be carefully removed and a closer check made with an EXPLOSIMETER. If there's any POSSIBILITY of the air containing ACETYLENE or HYDROGEN, the safety lamp should NOT be used.

Check and prepare this lamp carefully before you use it. To prepare it, first remove the fuel tank, fill with UNLEADED gasoline or naphtha, and wipe off ALL spilled fuel. Check the GAUZES and replace any that are defective. These gauzes constitute the safety factor of the lamp—check and handle them carefully. Also check the asbestos ASSEMBLY WASHERS to be sure they will form a perfect seal.

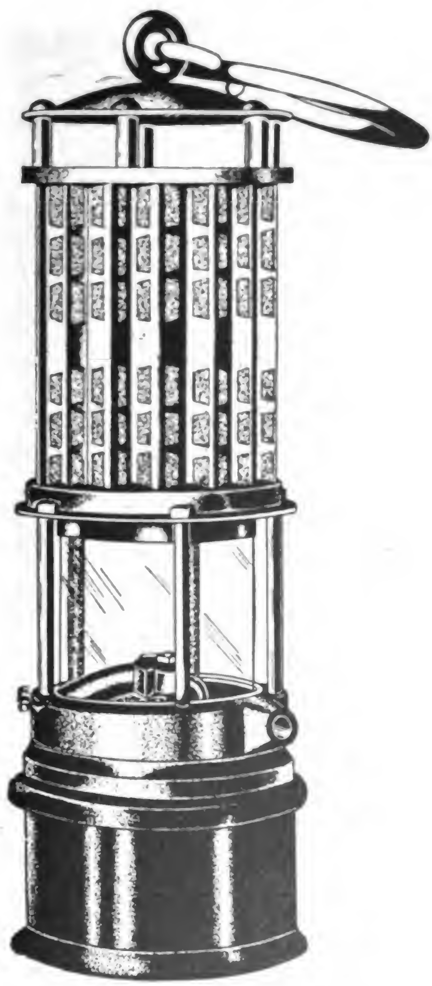


Figure 90.—Flame satety lamp.

Clear the glass GLOBE and inspect it for cracks or chipped edges. Take all possible precautions to prevent flame LEAKAGE. Then position the EXPANSION RING and place the SHIELD down over the gauze and glass, and screw the shield onto the tank tight enough to prevent the glass from being turned. Finally lock the lamp by tightening the LOCK SCREW with the key.

After the lamp is assembled, turn up the wick and ignite it. Allow the flame to burn about 5 minutes so that it will reach its normal operating temperature. Then adjust the flame so that its height is about 3/8 inch when burning in normal air. Test the safety of the assembly by blowing hard against the globe and seals. If the flame flickers there is a leak somewhere that you'll have to fix.

During the actual air testing, the lamp should always be kept in a VERTICAL position. Don't move the lamp suddenly from side to side or up and down. Move it SLOWLY and UNIFORMLY to prevent ignition of any explosive gases that may be present.

An air test is not valid unless all areas of a space are tested. Keep in mind that explosive gasoline and fuel oil vapors are heavier than air and will seek the lower levels of any compartment, space or void.

The effect of the OXYGEN CONTENT of the air on the flame of the safety lamp and on YOU is shown below—

% OXYGEN	EFFECT ON FLAME	EFFECT ON YOU
0	No flame.	Almost immediate death.
0–6	No flame.	Rapid collapse—death in from 6 to 8 minutes.
6–10	No flame.	Less rapid collapse—recovery with prompt treatment.
10–16	No flame.	Dangerous but seldom fatal.
16–18	Dim flame.	Lowered efficiency but usually no collapse.
18–21	Increasing flame.	Sufficient oxygen for breathing.
21	Bright flame.	None. Air is normal.

While the lamp is designed to test the purity of the air for breathing, it will indicate—to a limited extent—explosive conditions of the air. Such conditions are shown by the ACTION OF THE FLAME in the following manner—

ACTION OF FLAME	CONDITION OF AIR
Goes out rapidly.	Lack of oxygen for combustion.
Goes out with slight "pop".	Concentration of explosive gases.
Flares up brightly.	Lean concentration of explosive gases.
Flares up and goes out.	Rich concentration of explosive gases.

Any time the flame changes from its normal height and condition CAUTIOUSLY remove the lamp and check the air with an explosimeter.

THE EXPLOSIMETER

The EXPLOSIMETER (figure 91) is more accurate and reliable in testing the air for explosive gases than the lamp. This

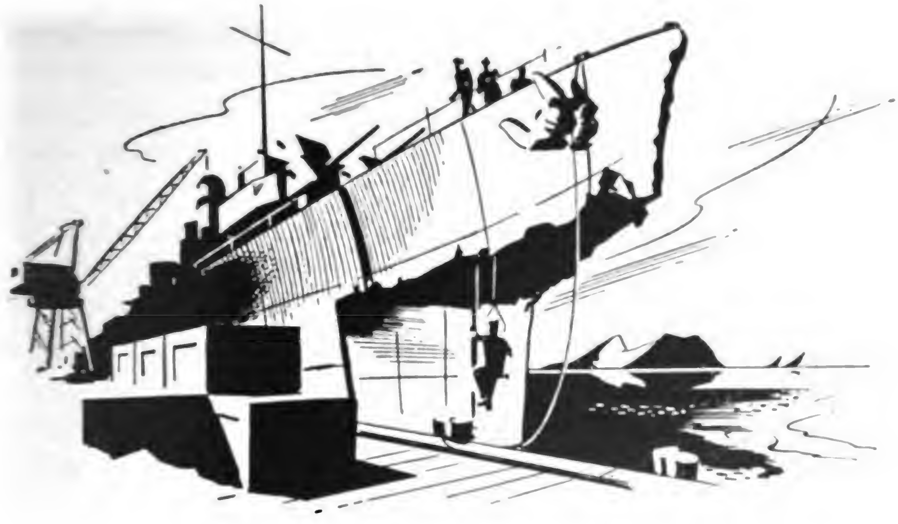
Figure 91.—Prevent explosions by using the explosimeter.

handy little device operates electrically to analyze small samples of the air. Its findings or analyses are read directly from the dial of the device. Any reading up to 60% EXPLOSIVE indicates a reasonably safe condition, particularly for emergency work such as welding, gas cutting, chiseling, sawing, etc. Try to reduce the percent of explosibility, however, by proper venti-

lation. Tests should be made frequently until the work is completed and the space or compartment secured.

Full instructions for using and maintaining the explosimeter are contained in a booklet supplied by the manufacturer. Actual operating instructions are printed on the cover of the device.

Use the meter carefully, follow the instructions, and there will be no blow-ups aboard your ship—at least not where you're working.



CHAPTER 11

SHORING

A JOB FOR EVERYBODY

Many ships have been saved, thanks to repair party personnel able to use SHORING. With it they've reinforced and held damaged bulkheads and decks, patches, WT hatch covers and doors, manholes and loose machinery.

All men in repair parties must have a thorough knowledge of shoring principles and construction methods. Other men, those not assigned to repair parties, should know enough about shoring to do a good emergency job. YOU, as a leading petty officer of an artificer rate, will be responsible as well for training men to do good shoring.

Your instruction should begin with the common HAND TOOLS used in shoring—saws, hammers, hatchets, and axes. It's surprising how many artificers can't properly use a hand cross-cut saw to cut off a timber at right angles. The average man will invaribly "ride the saw", thereby causing it to buckle, kink and pinch. It's up to you to teach your men the smooth, easy sawing stroke that's necessary for fast, true cuts. Have your men read the woodworking chapter in the basic Navy training course, *Use Of Tools*.

If you can spare a few short lengths of shoring, let your men practice making saw cuts at angles of 90°, 60° and 45°. With

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a little practice they should be able to saw angle cuts "BY EYE" —without any measuring or marking, other than for length.

If you have plenty of shores, you can have your men do some "dry" shoring jobs. Obtain permission to put up some shoring in a compartment where it can be left for several days. Then the various division officers will have a chance to send their men down to inspect the job and get some valuable pointers. When putting up practice shoring jobs avoid cutting your shores more than necessary because you'll seldom have an oversupply.

Start out with simple shoring jobs and work up to harder and more elaborate construction. As your men put up the shoring, give them pointers about such important factors as SPREADING THE PRESSURE, the comparative strengths of shores used in DIRECT COMPRESSION and CROSS-AXIAL construction, and WEDGING. Stress the use of measuring battens, filling pieces, cleats, sholes and strongbacks.

If you don't have spare shores for practice jobs, use strips and battens to build MOCK-UPS and MODELS. Make models to scale. Bulkheads and decks can be represented with sheets of sheet metal or plywood. Have a carpenter's mate rip you out some strips which can be used for shores, sholes, strongbacks, and filling pieces. It'll be easy to whittle out some miniature wedges.

While models are not as good as full size practice jobs, you can develop them into effective teaching aids. One advantage of models is that you can work out some of the more elaborate shoring problems—practice jobs that prohibit the use of full-size shores. Then too, you can keep the models and use them again and again.

TALK IT OVER

When your men have completed a practice shoring job, have them gather round and criticize the SHORING PRINCIPLES involved and the WORKMANSHIP. Have them point out desirable features as well as those that aren't so good.

During the discussion bring up questions such as—Is the shoring job EFFECTIVE? Could it be made just as effective with FEWER shores? Should MORE shores have been used? Is the shoring PRESSURE properly spread? Was the WEDGING done properly?

If one of the men thinks he could have done a better job by a different method or plan, give him a chance to prove his point. Then you and your men should look over his work and criticize it. Often this procedure will develop some good ideas.

SHORING LUMBER

Wood used for shoring is usually fir or yellow pine. It's supplied in standard mill sizes as 2x4, 2x6, 2x8, 4x4, 4x6, 6x6, 6x8, 8x8, and larger. Most of your shoring will be done with 4x4's and 6x6's. The sizes and lengths you'll have on your ship will depend largely on size of compartments and height of overheads.

The cardinal rule for shoring timbers is—SHORTER the SHORE the GREATER the LOAD IT WILL CARRY. The maximum length for any shore should be not more than the MINIMUM thickness of the shore multiplied by 30. Thus a 4x4, or a 4x6, cannot be more than 10 feet long or a 6x6 more than 15 feet.

Timbers, planks and boards used for shoring are named according to the manner in which they are used. Shoring names or terms are standard in the Navy. Teach your personnel these names and see that they use them correctly—

SHORE—a portable beam used for structural bracing and support, usually applied, singly or in combination, to exert pressure at 90° to the damage.

STRONGBACK—a bar or beam used to distribute pressure or weight along a deck, bulkhead, overhead, patch, hatch cover, or WT door.

SHOLE—A flat plate, such as a short piece of 2x12, used between shore and strongback as a filling piece and to help spread the pressure.

FILLING PIECE—timber used between end of shore and supporting structure, such as a coaming; also used to brace deck beams and stringers, and to block in between wedges.

WEDGE—a tapered block; they are used in pairs to apply pressure to shores.

CLEAT—small block which can be nailed to shoring members to help keep them in position.

BATTEN—Strip of wood (1x4 or 1x6) nailed to shoring members to keep them in position.

SUPPORT—length of timber (such as 2x4) placed vertically under horizontal strongback to keep it in position.

Some timbers, such as 4x4's, can be used as either shores, strongbacks, sholes, or filling pieces. Remember that the name depends more on USE than on size.

The dimensions of a WEDGE depend on the size of the shores with which it is used. A 4x4 shore requires wedges having dimensions of approximately 2 inches (butt thickness) x 4 inches (width) x 12 inches (length). Regardless of its size, a wedge should have a length of five to six times its butt thickness. Wedges made of yellow pine or fir hold better than those made of hard wood, but oak wedges are widely used in the larger sizes, because they have excellent resistance to crushing. Smaller wedges, particularly those used as plugs, should always be made of soft wood.

Shoring timbers are usually stowed in compartments of the Damage Control Deck—usually 2nd deck—so they'll be out of the way and yet readily accessible. Shoring wedges are nested together and held by nailing a batten lightly on one side. A nest of wedges made up in this manner must be lightly secured so they can be readily removed for use without tools. Made up in this manner, they should take up about the same space as one shore. Smaller wedges can be stowed with plugs in fire-resistant canvas bags secured in an out of the way place near the shores.

EQUIPMENT FOR SHORING

The following tools used for shoring are standard equipment for repair lockers—

Hand cross-cut saws	Cutting and welding torches
2-man cross-cut saws	Arc-welding machine or lead
Wood chisels	Hydraulic jacks
Hatchets and axes	Screw jacks
Mauls and sledges	Chain falls
Mallets	C-clamps and beam clamps
Nail hammers	Measuring battens

In addition to tools, you'll have nails, wooden plugs, sheet packing, bolts, nuts, washers, angle clips, welding electrodes, binding wire, turnbuckles, canvas and sand.

NAILS, sizes 8d, 12d and 20d, may be used to secure battens and cleats. Nails should not be driven in shoring members if there is any danger of splitting.

WHEN TO SHORE

"When in doubt, shore" . . . "Better safe than sorry" . . . "A stitch in time saves nine" are all good mottoes when applied to shoring. This is especially true if you have plenty of shoring lumber. If you're short of shoring lumber, you'll have to plan your work carefully and avoid unnecessary shoring. That's where you have to use your judgement as to which damage is most dangerous.

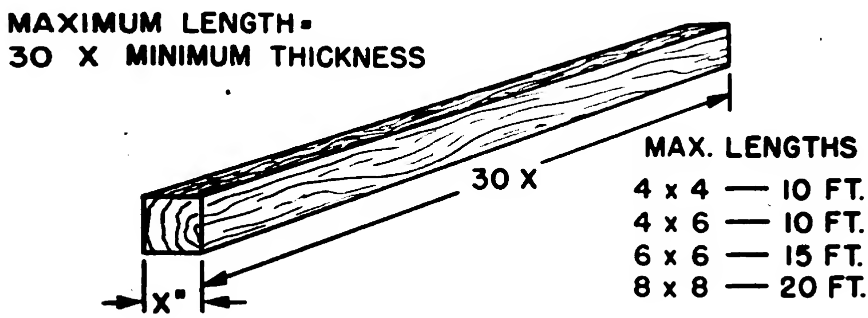

Figure 92.—Maximum length of shores.

If you have any of the following conditions, you will know that shoring is probably indicated and act accordingly—

PANTING BULKHEAD—even slightly panting bulkheads are dangerous because such panting will get progressively worse, due to metal fatigue.

WEAKENED SEAMS—either welded or riveted seams that are sprung or pulled apart are usually indicated by leaks.

DAMAGED STRENGTH MEMBERS—twisted, crushed, cracked or otherwise distorted beams, stanchions, stiffeners, frames, or stringers.

Decks, bulkheads, beams, stiffeners, frames, stanchions, coamings and seams are constructed with a high SAFETY FACTOR—are made several times stronger than normal operating conditions require. When these structures begin to give way you can be sure it's time to start shoring.

SHORING PRINCIPLES

Most shoring is done to support BULKHEADS which are endangered because of structural damage or weakness caused by the effect of hits or the pressure of floodwater. The PRESSURE

on the bulkheads of a flooded compartment is tremendous. It's greatest along the deck because pressure depends on the height of the water in the compartment. Pressure is also influenced—varied—by the headway of the ship and the amount of pitching and rolling.

Because pressure and stress are variable, you have to plan your shoring to take care of the MAXIMUM pressure and stress

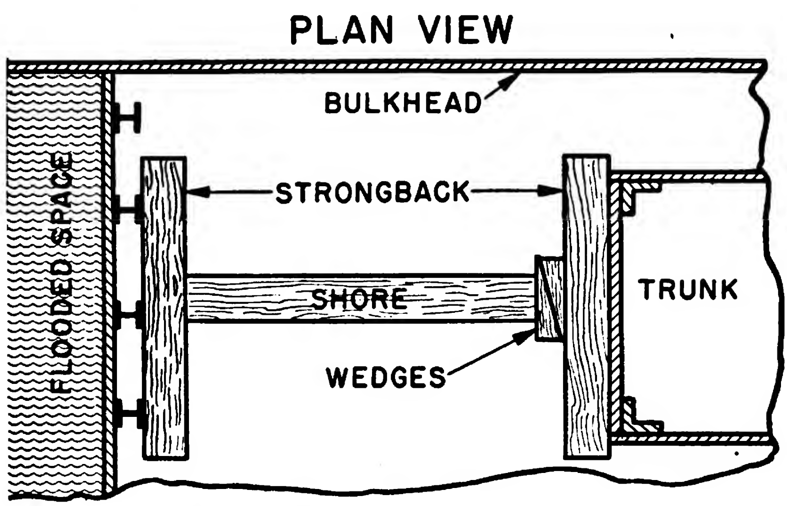

Figure 93.—Direct compression shoring job.

which may be encountered, plus a MARGIN OF SAFETY. You won't have time to work out the shoring problem mathematically and scientifically. You'll just have to use your own judgment as to when to shore and how much shoring is required.

There are no hard and fast rules for shoring but there are some guiding principles that must be kept in mind. Many of these are illustrated in the next few pages.

Here, in brief, are some of the important principles. First, SPREAD THE PRESSURE. Make full use of strength members by anchoring shores against beams, stringers, frames, stiffeners, stanchions, barbettes, and so forth.

Place the LEGS of the shoring structure against the strongback at an angle of 45° to 90°, if at all possible. Arrange WEDGES so that pressure will be EQUALIZED throughout the entire shoring structure, and use a MINIMUM number of wedges to apply required pressure.

Avoid feathered, notched or sharp ENDS on shores, and avoid applying excessive PRESSURE against a supporting structure.

When shoring a BULKHEAD, shore the ENTIRE bulkhead, even though the apparent damage is localized.

Always maintain a WATCH on the shoring. After shoring is done, consider the possibility of making TEMPORARY REPAIRS to weakened structural members. If there is any doubt that a shored bulkhead will hold, shore on back to the next bulkhead. The same principle applies to deck shoring.

Do NOT attempt to force a WARPED, SPRUNG or BULGED bulkhead BACK INTO PLACE. Plan your shoring to HOLD the bulkhead—or deck—AS IS.

SHORING A BULKHEAD

A shoring job like that shown in the plan view in figure 93 is exceptionally strong IF there is ADEQUATE SUPPORT available. Notice that the shore is in DIRECT COMPRESSION between the

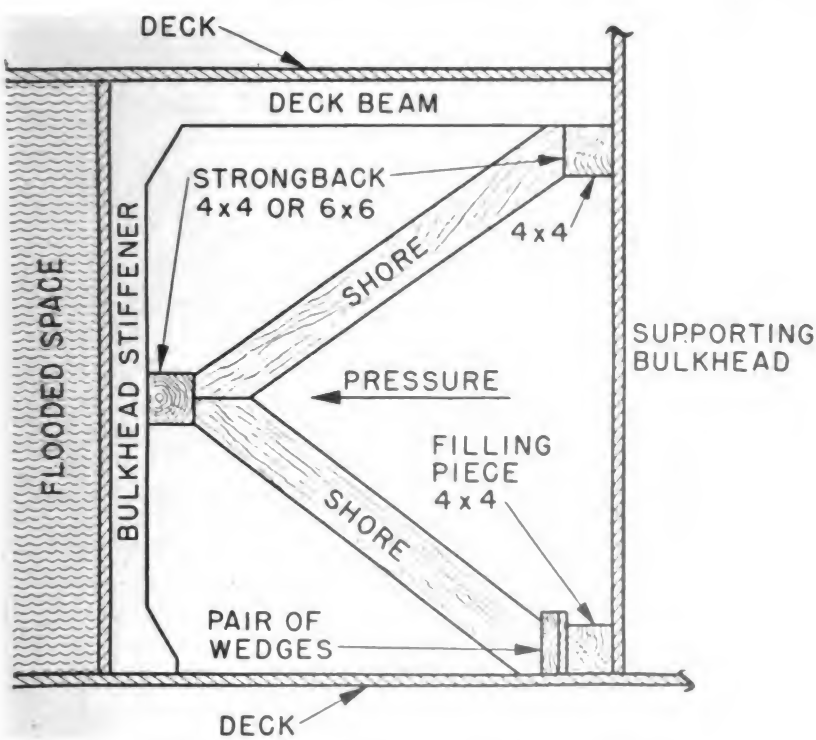

Figure 94.—A standard method of shoring.

strongback and the supporting structure. The strongback used should SPREAD THE PRESSURE over at least three frames or stiffeners.

Figure 94 shows a simple, effective method of shoring to the DECK and OVERHEAD. This method spreads the pressure so that

no one supporting area will be unduly weakened. Note how the filling pieces are used and how ONLY ONE SET of wedges supplies the pressure.

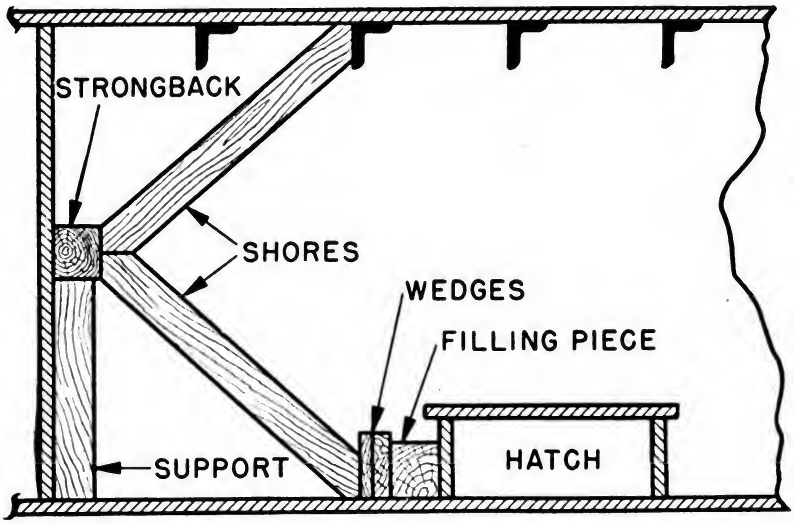

Figure 95.—Shoring to overhead and hatch coaming.

You can shore against a HATCH and to overhead BEAMS and STRINGERS if you use the system shown in figure 95. Note the use of the 4x4 filler piece along the hatch coaming. This piece must be used to spread the pressure along the coaming to keep it from giving way.

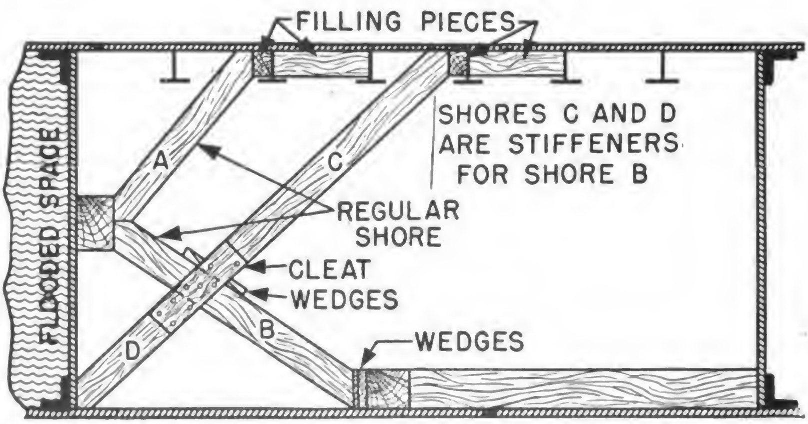

Figure 96.—Shoring to a distant bulkhead.

The shoring methods illustrated in figures 96 and 97 are applicable when a LARGE SPACE must be shored. Note the use of FILLING PIECES against and between the deck beams. These

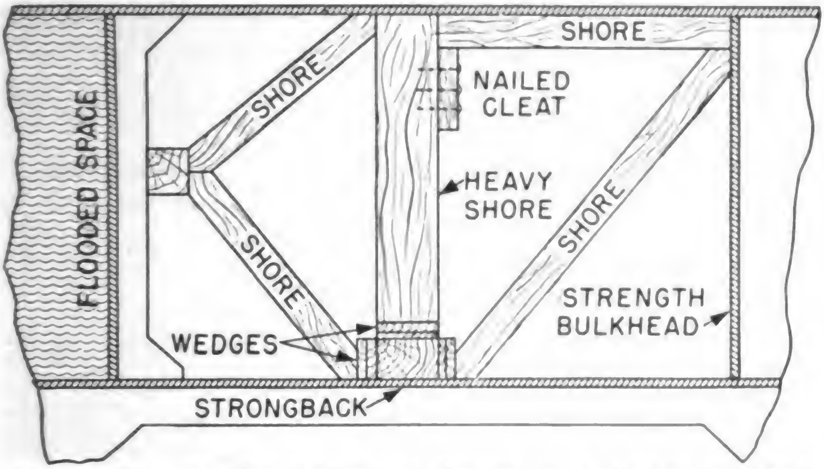

Figure 97.—Another method of shoring to a distant bulkhead.

pieces must be used to reinforce the beams. Cut the pieces slightly long and force them into place.

SHORING A DECK

DECK-shoring is usually of the DIRECT COMPRESSION type in which VERTICAL timbers—shores—support the load. The pressure is spread by STRONGBACKS placed on the supporting deck and under the beams or stringers of the damaged deck. Figure 98 shows a typical deck shoring job. Note the use of BATTENS.

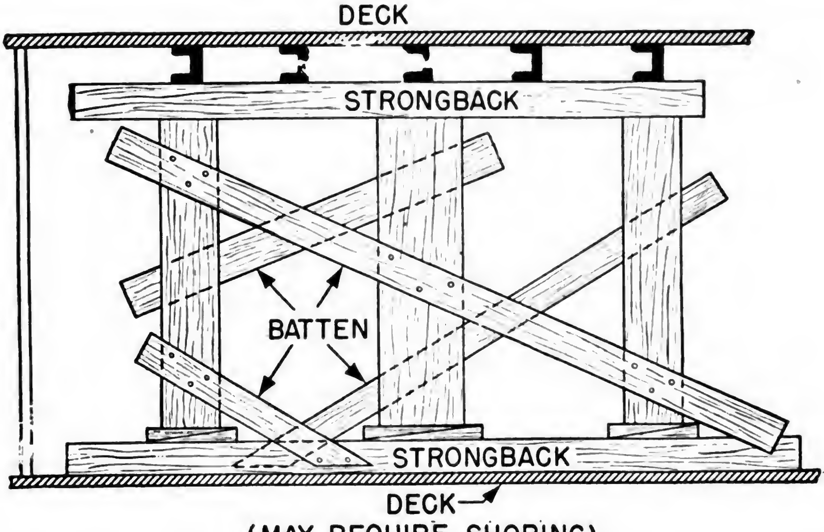

Figure 98.—Shoring from deck to deck.

Another example of deck shoring is pictured in figure 99 Here the forecastle deck of a cruiser is reinforced with shorin supported on the main deck. Here too, the PRESSURE MUST BI

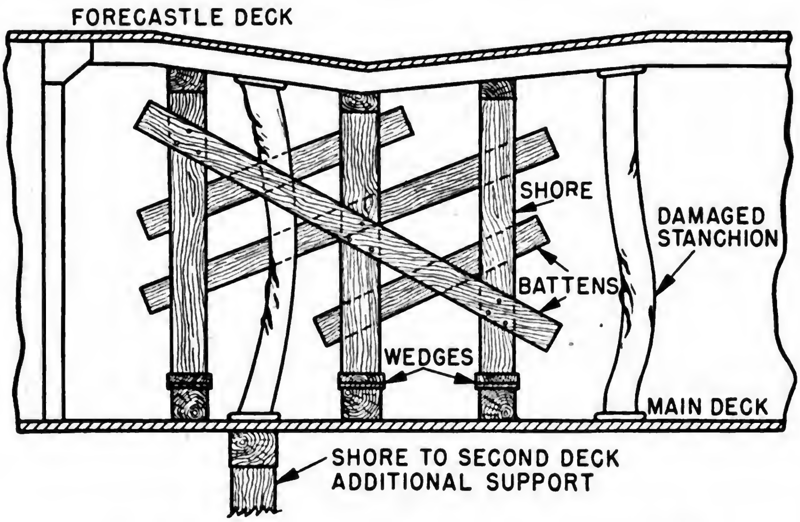

Figure 99.—Shoring support for a damaged deck.

SPREAD. That's why you may also have to shore under the main deck; that is, to the second deck.

A deck that is BULGED UPWARD in one spot can be shored by

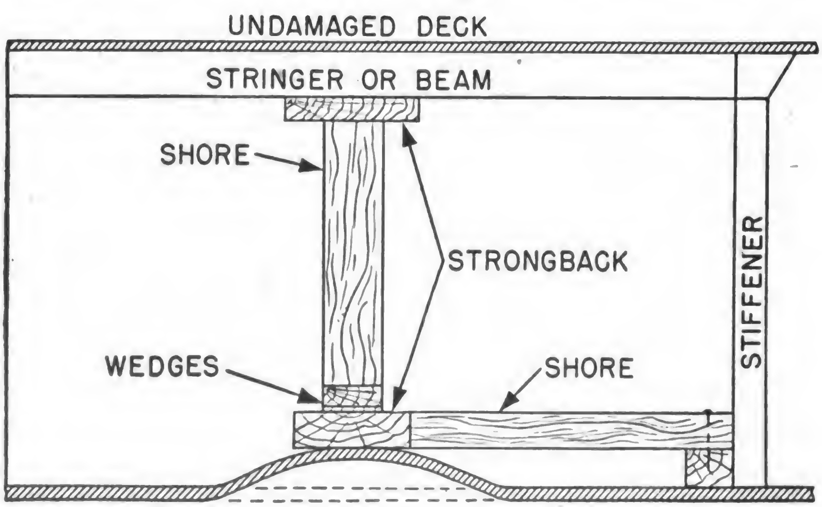

Figure 100.—Shoring a bulged deck.

the method shown in figure 100. A strongback is placed over the bulge and shored to the overhead. Note the use of a shore to prevent the strongback from slipping off the bulge. If nec-

essary another shore can be used to prevent the strongback from slipping in the other direction.

SHORING HATCHES AND DOORS

When a HATCH or DOOR is involved, the entire hatch cover or door must be shored by the method diagrammed in figure 101. Don't take any chances with such openings because they are the

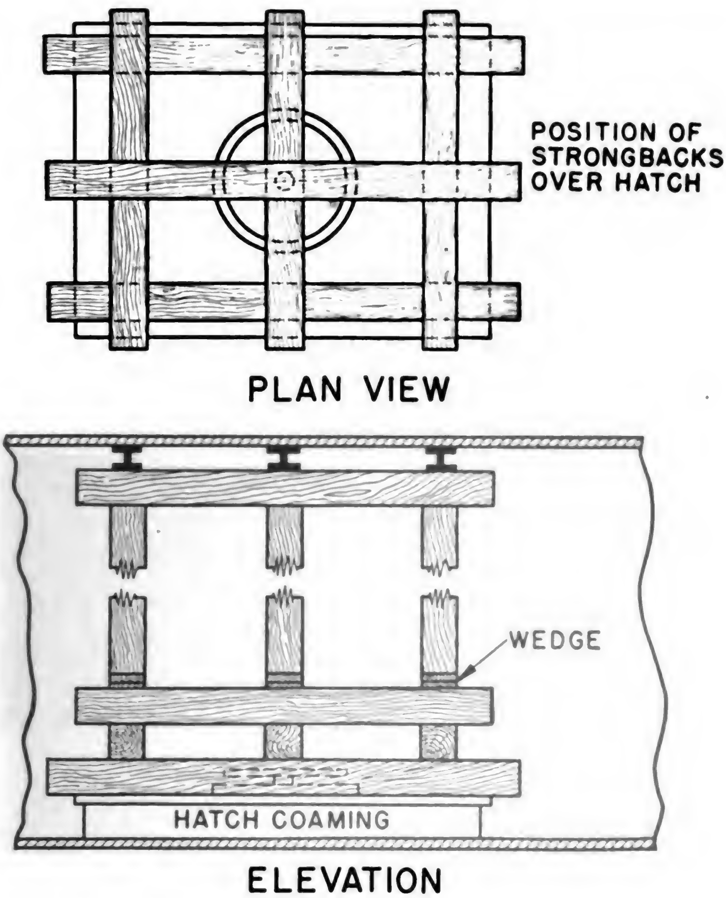

Figure 101.—Shoring a hatch (or door).

WEAKEST PART of the bulkhead. And the basic principle of shoring still holds—SPREAD THE PRESSURE, both on the hatch cover or door and on the supporting structure.

If a hatch or door is badly damaged, you must use PACKING—blankets, mattresses or pillows—under your sholes and strongbacks. More shores are required for such a job. Add as many as you think necessary.

USE OF WEDGES

Use as FEW wedges as possible to obtain the desired pressure. Drive them UNIFORMLY from BOTH sides so the shore end will not be forced out of position. Use ONLY ONE PAIR of wedges at any one spot. A number of wedging tips and pointers are clearly illustrated in figure 102.

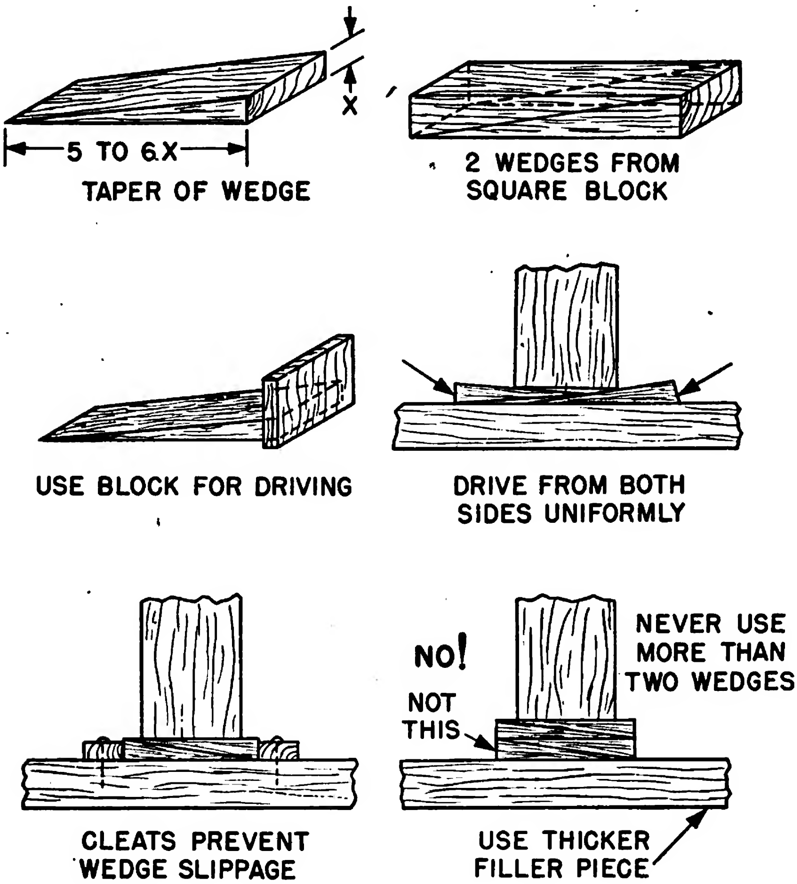

Figure 102.—Watch your wedging methods.

FILLING PIECES are often used to block in between wedges to prevent them from loosening. This is easily done when shoring between decks (figure 103). Note that provision is made for taking up the wedges. After they are driven up, you can place small blocks behind them to prevent slippage.

SHORING SENSE

Don't overlook some of the LITTLE THINGS when you're planning or setting up shoring—as, for example, shoring against a deck beam without reinforcing the beam. Don't weaken shores by notching the ends. Some miscellaneous shoring principles are pictured in figure 104.

MACHINERY that has been torn loose or weakened can often be jacked or pulled back in place and then shored to hold it

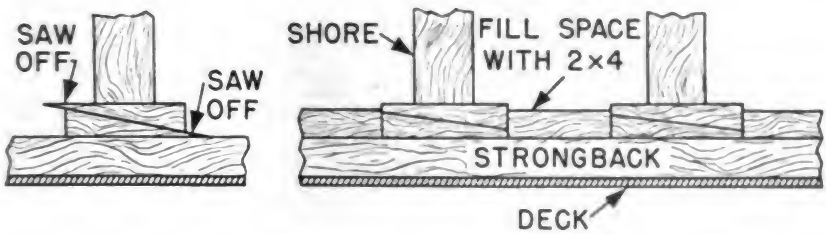

Figure 103.—Locking wedges in place.

securely in position. Get it back in place with levers, chain falls and jacks, and then use plenty of strong shores and strongbacks to keep it there. And don't forget you have to spread the pressure to avoid further damage.

PATCHES are shored in much the same manner as bulkheads, hatches and doors.

SHORING WITH METAL

If time and material permit, you can shore effectively with steel pipe, angles, bars and beams. METAL SHORES can be used with wooden strongbacks but a shole made of steel plate should be placed between the shore end and the strongback. Metal shores have one advantage over wood in that they can be welded into place to effect a more permanent repair.

Lengths of PIPE are excellent for shoring under decks. A pipe shore will be stronger if it is tightly packed with SAND. Such shores should be supported by sholes of heavy steel plate.

SHORING SUMMARY

Don't take any chances with weakened bulkheads, decks and structural members—SHORE. Plan your shoring jobs to use a

minimum number of shoring timbers to secure the maximum strength required.

SPREAD THE PRESSURE over the shored area and over the supporting area and members.

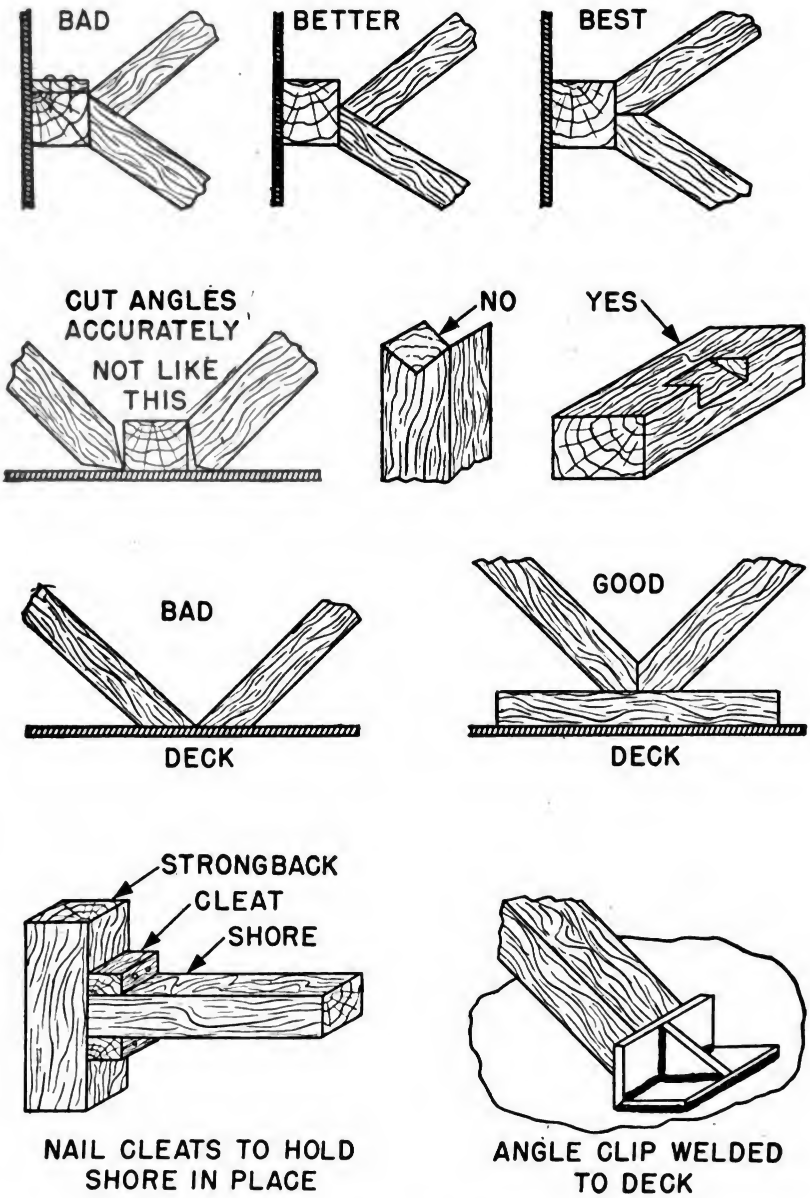

Figure 104.—Miscellaneous shoring principles.

DON'T attempt to FORCE decks and bulkheads BACK INTO PLACE. Just try to hold them as they are to prevent further damage. Arrange shores, strongbacks, sholes, supports, filling pieces and wedges so they will STAY PUT.

When the shoring job is finished, SET A WATCH to take up the wedges and see that the shoring job CONTINUES to hold and stay put.

If it does, you're O.K. and have proved you're a real expert at your trade, fully deserving of your new rate as Metalsmith 1c or Chief Metalsmith.

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QUIZ

CHAPTER 1

THE METALSMITH AFLOAT

1. What additional responsibilities will you have when you advance from M2c to M1c?
2. How should you form opinions of the abilities of a man who works in your gang or shop?

CHAPTER 2

SHOP MANAGEMENT AND SAFETY

1. Should you train your men to be specialists in certain lines or to be good all-round metal workers?
2. Why should work not be started without a job order?
3. How can you tell whether a shop is efficient and well-run?
4. Why should each man have a locker in which to store the common tools he ordinarily uses?
5. Few accidents are the result of failure of tools, machines and other equipment. What, then, is the greatest cause of accidents?

CHAPTER 3

VENTILATION

1. What is the principal disadvantage of the vaneaxial fan?
2. What shape of duct cross-section offers the least resistance to moving air?
3. How can you stop panting of rectangular duct walls?
4. For what purpose are scoops and splitters used?
5. Why do supply terminals have a flared shape?
6. What fireproof insulation material is used on ventilation ducts?

CHAPTER 4

SHEET METAL PATTERN DEVELOPMENT

1. What method of development is used to make patterns for conical-shaped objects?
2. What method is used to develop a cylindrical object?
3. When you want to make a development for an intersection of round ducts of different diameters, what line must be established before the two patterns can be made?
4. Why is it necessary to use the triangulation method for some sheet metal developments?
5. How can you teach your strikers and lower-rated men to make simple sheet metal developments?

CHAPTER 5

OXYACETYLENE WELDING AND BRAZING

1. What is the purpose of postheating parts that have been welded or brazed?
2. An oxidizing flame is used when welding or brazing what materials?
3. When you make out a request for a certain item of supply, why should you indicate the proposed use of the item?
4. What is the disadvantage of using a flux that contains flourine?
5. Why is a flux usually used when non-ferrous metals are welded or brazed?
6. Why is silver solder preferred to brass for joining many metals?
7. What gas should be used for fuel in underwater cutting?

CHAPTER 6

ARC-WELDING

1. What special care must be taken when you are welding steel that contains more than 0.50 percent carbon?
2. What polarity is used for underwater d-c welding?
3. How can underwater cutting of steel be done with the arc?

4. The efficiency of arc welding is largely due to what scientific development?
5. Why should electrodes be kept in their original packages until they are needed?
6. The gas cutting torch is not satisfactory for cutting non-ferrous metals. How can you cut them with an arc?
7. What special precautions must be taken when you are welding non-ferrous alloys containing zinc and lead?
8. Why is it dangerous to weld containers that have held inflammable liquids or gases?
9. Cored castings may explode if they are heated. What causes the explosion?

CHAPTER 7

HARD-FACING

1. What are the three general types of hard-facing materials?
2. Which hard-facing material is almost as hard as a diamond?
3. How does carbon content affect the hard-facing of steel?
4. Why are brasses and bronzes seldom hard-faced?
5. Most welders prefer to hard-face by the oxyacetylene method rather than with the arc. Why?
6. How are hard-facing deposits finished to shape and size?
7. What difficulty is sometimes encountered when extremly hard facings are applied to working surfaces?

CHAPTER 8

METAL TESTS

1. What is the tensile yield point of a metal?
2. The free-bend test is a method of measuring what metal property?
3. Why is the guided-bend test considered more accurate than the free bend test?
4. What three machines are commonly used to make non-destructive tests of metal hardness?
5. For what purpose is the spark test usually used?
6. What simple hardness testing device works on the principle of indentation comparison?
7. Which hardness testing machine utilizes the principle of rebound?

CHAPTER 9

DAMAGE CONTROL ORGANIZATION AND TRAINING

1. What is the purpose of damage control?
2. What are two good methods of teaching a man to know his own ship?
3. What is the cardinal principle used in making repair party assignments?
4. What men aboard ship are responsible for watertight integrity?
5. When should you, and your men, look for violations of watertight integrity?

CHAPTER 10

EMERGENCY DAMAGE REPAIR

1. When compartment is flooded, what should be done about it?
2. What factors determine the amount of flood water coming through a hole in a bulkhead?
3. What is the most important principle to follow when flood water is coming through a hole?
4. If one type of patch fails to stop a leak, what should you do?
5. Why are soft wood plugs better than hard wood for plugging leaks?
6. How can you prevent a crack from becoming longer?
7. What advantage does a wooden box patch have over a steel box patch?
8. What is the normal oxygen content of the air?
9. What is the appearance of the flame of a safety lamp when the oxygen content of the air is about 12 percent?
10. Why is it a good idea to make frequent explosimeter tests in a compartment in which the air is of doubtful purity?

CHAPTER 11

SHORING

1. What mistake is often made by inexperienced men when they use a hand saw to cut shores to length?

2. Why are shores usually kept on the 2nd deck?

3. Why is a panting bulkhead dangerous?

4. What is the basic principle of shoring?

5. How much of the area of a damaged bulkhead should be shored?

6. Should damaged decks and bulkheads be forced back to their normal positions?

ANSWERS TO QUIZ

CHAPTER 1

THE METALSMITH AFLOAT

1. A M1c has more responsibility for supervision and training than a M2c.
2. Form your opinions of a man's abilities slowly and with an open-minded, unprejudiced and impartial attitude. Remember that your opinion may affect the man's naval career.

CHAPTER 2

SHOP MANAGEMENT AND SAFETY

1. Train your men to be good all-round metal workers so that any man can handle any job that comes up.
2. Get a job order before you start work on a new job to avoid any confusion or misunderstanding, and to keep the records straight.
3. You can determine the efficiency of a shop by making a quick inspection or survey of the tool and stock stowage and condition, equipment condition and general neatness and cleanliness.
4. When each man has his own tool locker and tools he takes more pride in keeping his tools in good condition.

CHAPTER 3

VENTILATION

1. The vaneaxial fan is dangerous when used in systems that might carry explosive gases.
2. Round ducts offer least resistance to moving air.
3. Panting can be reduced or stopped by the use of angle stiffeners.
4. Scoops and splitters are used to apportion the air to branch mains and branches.
5. Supply terminals are flared to reduce the velocity of the air as it enters the supplied space.
6. Fibrous glass is a fireproof insulation material used on ventilation ducts.

CHAPTER 4

SHEET METAL PATTERN DEVELOPMENT

1. Use radial development to make patterns for conical-shaped objects.
2. Parallel development is used to make patterns for cylindrical jobs.
3. The development cannot be made for intersecting cylinders of different diameters until the line of intersection is established.
4. Triangulation must be used to determine the true lengths of lines on the irregular surface to be developed.
5. Teach your strikers to make simple developments by laying out patterns on heavy wrapping paper. Have the men cut out the patterns and assemble them as a test of their ability.

CHAPTER 5

OXYACETYLENE WELDING AND BRAZING

1. Welded or brazed parts are postheated to equalize the rate of cooling.
2. An oxidizing flame is used with most of the copper alloys — brasses and bronzes.
3. If you indicate the use of the item, and the item is not immediately obtainable, an acceptable substitute may be provided.
4. Flourine is poisonous; so avoid breathing the fumes of fluxes containing it.
5. A flux must be used with most non-ferrous metals to remove any oxides already present and to prevent further oxidation as a result of heating. This is the principal reason a flux is used on any metal.
6. Silver solder is preferred to brass and bronze filler metal for many jobs because it can be applied at lower temperatures with less changes in the properties of the joined parts.
7. Hydrogen should be used as fuel for underwear cutting.

CHAPTER 6

ARC-WELDING

1. Avoid overheating the base metal when you are welding steel that contains more than 0.50 percent carbon.
2. Use straight polarity for underwater d-c welding.

3. Underwater cutting of steel can be done with the d-c arc, using straight polarity and a stream of oxygen to support combustion.
4. The present day efficiency of arc-welding is largely due to the rather recent development of greatly improved electrode coatings.
5. Moisture causes deterioration of electrode coatings. If you keep electrodes in their original containers there will be less danger of moisture absorption.
6. The carbon-arc can be used for cutting (burning) non-ferrous metals.
7. Avoid breathing the poisonous fumes of lead and zinc. Provide extra ventilation and plenty of it when you are heating alloys containing these elements.
8. It is dangerous to weld containers that have held inflammable liquids because such containers may explode when they are heated. Such containers can be safely welded only when they have been filled with inert gas or water or when they have been thoroughly steamed with live steam for several hours. The best policy is just not to do any welding, brazing or cutting on such containers.
9. Cored castings and other assemblies having enclosed spaces will explode when heated because of the tremendous pressure caused by expansion of trapped liquids and gases. All castings and closed fittings and assemblies should be thoroughly vented before being heated.

CHAPTER 7

HARD-FACING

1. The three general types of hard-facing materials are iron base alloys, tungsten or cobalt alloys, and tungsten carbide.
2. Tungsten carbide is almost as hard as a diamond.
3. Low carbon steel is easily hard-surfaced. The higher the carbon content, the more difficult is the hard-facing job and the less satisfactory the finished product.
4. Brasses and bronzes are seldom hard-faced with special alloys because their melting points are below those of the hard-facing materials.
5. The oxyacetylene method is preferred for hard-facing because it permits better heat control and better control of the degree of penetration of the facing alloy into the base metal.
6. Because of their extreme hardness, hard-faced surfaces must be finished by grinding. They cannot be machined or filed.
7. Extremely hard surfaces tend to crack and chip. They have little resistance to shock or impact.

CHAPTER 8

METAL TESTS

1. The yield point of metal under tension is the point at which there is a definite increase in length with no increase in load.
2. The free-bend test measures the ductility of the metal.
3. The guided-bend test is considered to be better than the free-bend test because specimens are all shaped to the same uniform radius by the guided-bend machine.
4. Non-destructive hardness tests are commonly made with Brinell, Rockwell and Shore machines. There is also a Vickers hardness test.
5. The spark test is most often used for identification of ferrous metals.
6. Testing by indentation comparison is done with the Brinell Meter.
7. The Shore scleroscope uses the pounding ball principle for testing and comparing the hardness of metals.

CHAPTER 9

DAMAGE CONTROL ORGANIZATION AND TRAINING

1. The purpose of damage control is to KEEP THE SHIP AFLOAT AND MANEUVERABLE WITH ALL ARMAMENT AND EQUIPMENT OPERATING AT MAXIMUM EFFICIENCY.
2. You can teach a man to know his own ship by using the damage control plates and by comprehensive tours and inspections of the ship.
3. The cardinal principle used in making repair party assignments is to separate the men of various ratings so that all men of one rate or specialty will not be wiped out by an unlucky hit. This method also provides each party with men who have a maximum variety of skills for meeting any situation that might come up.
4. Aboard ship ALL MEN are responsible for watertight integrity.
5. Look for watertight integrity violations all the time — even when you're on your way to chow.

CHAPTER 10

EMERGENCY DAMAGE REPAIR

1. You can do very little about a flooded compartment immediately. What you should do is to try to set up and maintain a flooding boundary to prevent progressive flooding.

2. The amount of flood water coming through a hole depends on the area of the hole and the depth of the hole (usually the depth of the hole is the distance of the hole below the waterline).

3. The most important principle to follow when water is coming through a hole is to get SOME KIND of plug or stopper in the hole. Remember that even partial stoppage is a big help to the pump.

4. If one kind of patch fails to stop a leak, try another type.

5. Soft wood plugs swell more and swell faster than hard wood plugs; so they are superior for use as leak stoppers.

6. To prevent a crack from growing longer drill holes at each end.

7. The advantage of a wooden box patch over one made of steel is that it can be chopped off to fit the contour of the plating around the hole.

8. The normal oxygen content of the air is 21 percent.

9. If the oxygen content of the air were only 12 percent there would be no flame.

10. Frequent use of the explosimeter should be made if the air is of doubtful purity because explosive or poisonous gases may enter the compartment between tests.

CHAPTER 11

SHORING

1. Inexperienced men tend to "ride the saw" when they are cutting shores to length. Teach your men to remember that "easy does it".

2. Shores are usually stored on the second deck because that deck is usually the damage control deck and the lowest deck that is readily accessible.

3. A panting bulkhead is dangerous because it is likely to get worse.

4. The basic principle of shoring is SPREAD THE PRESSURE.

5. When a bulkhead is damaged, don't shore only the damaged area. Shore the entire bulkhead in the damaged compartment. Shore bulkheads in adjacent compartments if necessary to maintain the flooding boundary.

6. Don't attempt to force damaged decks and bulkheads back into place — just try to hold them as they are. Otherwise you'll do more harm than good.

QUALIFICATIONS

METALSMITH 1c

(A) PRACTICAL FACTORS.

(*a*) DAMAGE CONTROL.—Demonstrate ability to act as a petty officer in charge of a damage control party.

(*b*) SUPERVISION AND TRAINING.—Demonstrate ability to supervise the work and training of lower ratings.

(*c*) PIPE.—Demonstrate proficiency in the bending of pipe. Demonstrate ability to make templates and build targets.

(*d*) FABRICATION.—Demonstrate ability to lay out and perform all metal work jobs that may be required aboard ship.

(*e*) LAYING OUT.—Demonstrate ability to develop and show by rough sketches the method of laying out and fabricating the following; funnels, 45° ells, 90° ells and tees.

(*f*) FORGING.—Demonstrate ability to forge metal shapes and temper hand tools, observing all safety precautions.

(*g*) WELDING.—Demonstrate ability and skill in performing complex oxyacetylene and arc welding jobs. Be able to take charge of welding activities in own ship or station.

(*h*) D-5206.07 (2) (A) (Practical Factors for Metalsmith 2c.)

(B) EXAMINATION SUBJECTS.

(*a*) DAMAGE CONTROL.—Know the purpose of damage control and the duties that are likely to be performed by the petty officer in charge of a repair party.

(*b*) VENTILATING SYSTEM.—Show by diagram the arrangement of the ventilating system in own ship.

(*c*) HOLLOW CASTINGS.—Know what procedure is required before the welding of hollow castings is attempted.

(*d*) WELDING.—Familiarity with the following:

(i) Joint design requirements as set forth in General Specifications for Inspection of Material.

(ii) "Specifications for Welding", General Specifications.

(iii) "Welding and Brazing", General Specifications for machinery.

(*e*) HEAT TREATING.—Knowledge of heat treating and the special treatment required for alloys. Know the safety precautions involved.

(*f*) METAL TESTS.—Know how standard hardness tests are made and what equipment is used.

(*g*) D-5206.07 (2) (B) (Examination Subjects for Metalsmith 2c.)

CHIEF METALSMITH

(A) PRACTICAL FACTORS.

(*a*) Damage Control.—Demonstrate ability to organize and direct damage control parties.

(*b*) Supervision.—Demonstrate ability to organize and to take charge of the Metalsmith shop. Be able to take charge of the welding ship, and to instruct and qualify candidates for welder, third class.

(*c*) Metal Tests.—Demonstrate ability to conduct standard hardness tests and to operate standard hardness testing equipment, provided that own ship or station is so equipped.

(*d*) D-5206.07 (3) (A) (Practical factors for Metalsmith 1c.)

(B) EXAMINATION SUBJECTS.

(*a*) C & R Repairs.—Know how to plan and estimate time, cost, and material for any C & R metal repair job, or alteration required to be completed on board ship or at a navy yard.

(*b*) C & R Machinery.—Understand the operation and use of all shipboard machinery under the cognizance of the C & R Department.

(*c*) General Specifications.—Thorough knowledge of "Specifications for Welding", General Specifications, "Welding and Brazing", General Specifications, for Machinery.

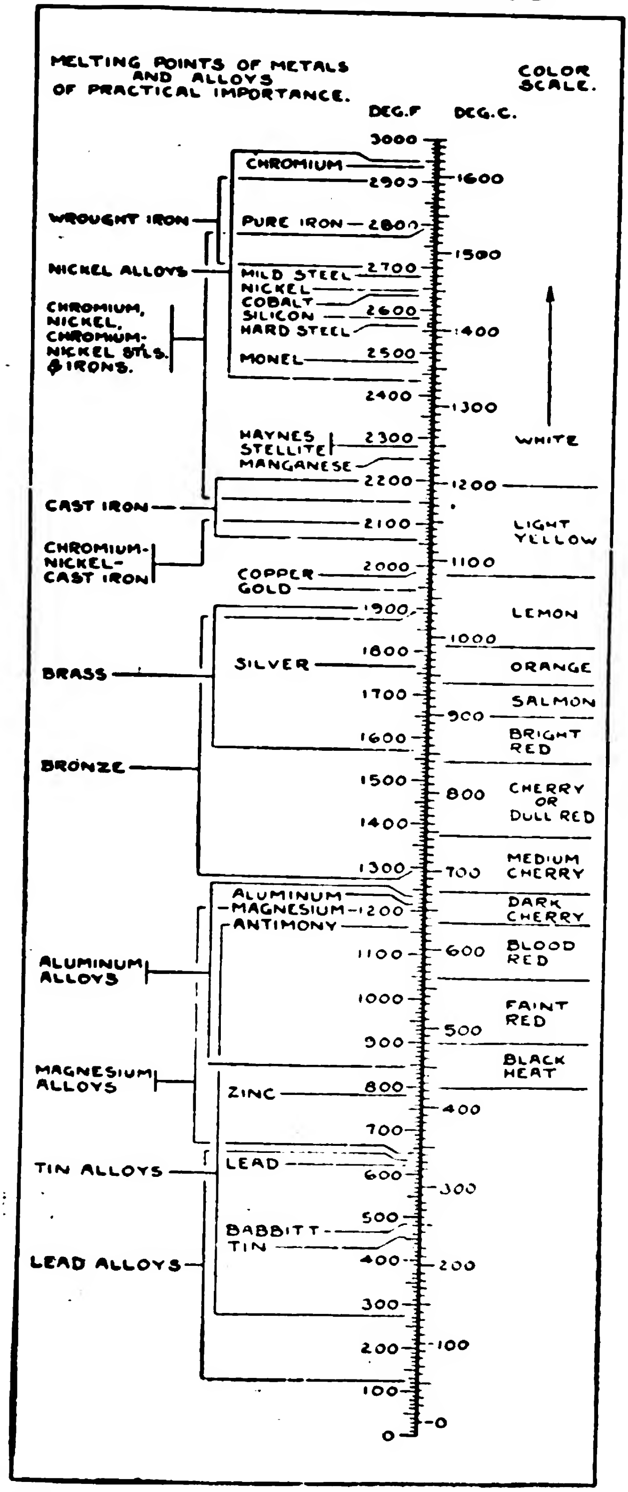
(*d*) Damage Control.—Thorough knowledge of damage control organization aboard own ship.

(*e*) Records and Reports.—Know the records to be kept and the reports to be submitted by the Chief Metalsmith.

(*f*) D-5206.07 (3) (B) (Examination subjects for Metalsmith 1c.)

APPENDIX I

MELTING POINTS OF METALS AND ALLOYS



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APPENDIX II

METALSMITH TRAINING FILMS

FILMS ABOUT THE USE OF TOOLS—

SN-247—Drills and Drilling.
MN-142—Drilling in Metal, Wood and Plastics.
SN-6—Sharpening Drills—Grinding Tools.
MA-2087b—Hand Measuring and Power Tools—Portable Electric Drills.
MA-1929c—The Use of Service Hand Tools—Chisels.
MA-1929d—The Use of Service Hand Tools—Hammers.
MA-1929f—The Use of Service Hand Tools—Hacksaws.
MA-1929b—The Use of Service Hand Tools—Pliers and Screwdrivers.
MA-1929e—The Use of Service Hand Tools—Punches, Drifts and Bars.
MA-1929a—The Use of Service Hand Tools—Wrenches.
SN-1575—Layout Tools and Measuring Instruments.
SC-825—The Use of Measuring Tools—The Rule.
MA-2087a—Hand Measuring and Power Tools—Operation and Care of Portable Bench Grinders.
MN-159—Filing.
MN-71—Hand sawing.
SN-1453—Hacksaw.

FILMS ABOUT SHEET METAL WORK—

SN-1035—Simple Calculations for Flat Layouts.
SN-1036a—How to Develop an Intersection—Part I.
SN-1036b—How to Develop an Intersection—Part II.
MN-2339d—Shipbuilding Skills—Sheet Metal Work—Transition Piece, Square to Round, Layout and Fabrication.
MN-2339a—Layout and Fabrication—Shipbuilding Skills—Sheet Metal Work—Vaned Turns.
SN-292—Making a Round Metal Container.
MN-26—Hand Method of Forming Sheet Metal.
MN-29—Bar Folder.

MN-24—Cornice Brake.
MN-27—Rotary Machines.
SN-57—Soldering.
SN-643—Soldering Practice.

FILMS ABOUT WELDING AND BRAZING—

MN-1921g—Safety for Welders.
SN-2655—Welding Equipment.
MC-541a—The Inside of Arc Welding—Fundamentals.
MC-541b—The Inside of Arc Welding—Flat Position.
MC-541c—The Inside of Arc Welding—Horizontal Position.
MC-541e—The Inside of Arc Welding—Vertical Position.
MC-541f—The Inside of Arc Welding—Overhead Position.
MC-541d—The Inside of Arc Welding—Alternating Current in Flat and Horizontal Positions.
MA-417—Construction and Use of Oxyacetylene Welding Equipment.
SN-2667—Setting Up and Lighting the Oxyacetylene Equipment.
SN-2660—Welding Aluminum Flat Sheet.
SN-130—Vertical Welds—Steel.
SN-2656—Fillet Welds.
SN-94—Qualifications Test for Welders.
SN-137—Oxyacetylene Cutting.
SA-484—The Blacksmith and the Welder.
SN-2658—Brazing and Silver Soldering.
SN-2657—Welding Stainless Steel.
SC-1752—Brazing Carboloy.

FILMS ABOUT COPPERSMITHING AND PIPEFITTING—

MN-2346a—Shipbuilding Skills—The Coppersmith—Flaring and Reducing.
MN-2346b—Shipbuilding Skills—The Coppersmith—Working out Branches from a Line.
MN-2337a—Shipbuilding Skills—Pipefitting, Removing a Section of Piping Aboard Ship.
MN-2337b—Shipbuilding Skills—Pipefitting—Making a Wire Template.

MN-2337d—Shipbuilding Skills—Pipefitting—Fitting and Installing a Section of Piping Aboard Ship.
SN-56—Fabrication of Tubing.

MISCELLANEOUS TRAINING FILMS—

MN-61a—The Chemistry of Fire.
MN-61b—School of the Firefighter.
MN-61d—Rescue Breather Apparatus.
SN-34—Fire Extinguishers, Use of.
MN-37—Behind the Shop Drawing.
MN-2334a—Nomenclature of Ships—Fundamental Lines and Sections.
SN-2335m—Shipbuilding Skills—Ship's Blueprints—Basic.
SN-76a—Painting Ships and Boats—Preparing the Surface for Paint—Preparing Paint.
SN-76b—Painting Ships and Boats—Applying Paint—Safety Precautions.
SN-76c—Painting Ships and Boats.
SN-52—Shop Teaching.
MN-128—Giving a Shop Demonstration.
MN-61f—Damage Control—Elements of Stability.

Note: Some of these films will become obsolete and not available. When you request a film ask for a substitute if the desired film cannot be obtained.

APPENDIX III

FIRE-FIGHTING CHART

Combustible	Type fire	Extent	Extinguishing agents
Woodwork, bedding, clothes, combustible stores........	A	Small...	1. Portable CO_2 extinguishers. 2. Solid water stream. 3. Low-velocity fog. 4. Foam.
		Large...	1. High-velocity fog. 2. Solid water stream. 3. Foam. 4. CO_2 (fixed system).
Electrical and radio apparatus...	C	Small...	1. (De-energize affected circuits) 2. Portable CO_2 extinguishers. 3. High-velocity fog.
		Large...	1. (De-energize affected circuits) 2. Portable CO_2 extinguishers or CO_2 hose reel system. 3. High-velocity fog. 4. Foam application.
Paints, spirits, inflammable stores...	B	Small...	1. Portable CO_2 extinguishers. 2. Low-velocity fog. 3. Foam.
		Large...	1. CO_2 (fixed system). 2. High-velocity fog. 3. Foam. 4. Installed sprinkling system. 5. Steam smothering.
Explosives	B	Small...	1. Water immersion. 2. Magazine sprinkling. 3. Solid water stream.
		Large...	1. Water immersion. 2. Magazine sprinkling and flooding. 3. Solid water stream.

Combustible	Type fire	Extent	Extinguishing agents
Gasoline and kerosene	B	Small...	1. Portable CO_2 extinguishers. 2. Low-velocity fog. 3. Foam. 4. Fog-foam. 5. Installed fog spray (to prevent spread).
		Large...	1. Foam. 2. Fog-foam. 3. High-velocity fog. 4. Fog-spray. 5. CO_2 (fixed system). 6. Installed sprinkling system (to prevent spread). 7. Water curtains (to prevent spread).
Fuel oil and Diesel oil.........		Small...	1. Portable CO_2 extinguishers. 2. Low-velocity fog. 3. Foam.
		Large...	1. Foam. 2. Fog-foam. 3. High-velocity fog. 4. CO_2 (fixed system). 5. Steam smothering.
Incendiary bombs....	.....	....	1. (Throw overboard). 2. Solid water stream. 3. High-velocity fog. 4. Sand. 5. Immersion in water.
Films, celluloid, etc.	A....	....	1. Water immersion. 2. Solid water stream. 3. High-velocity fog.

Extinguishing agents are listed in the order of their preferred use. They act in the following manner: (1) Water—wetting and cooling, (2) Fog—wetting, cooling, smothering, (3) Foam—smothering, (4) Fog-foam—smothering, cooling, (5) CO_2—smothering, (6) Steam—smothering, (7) Sand—smothering.

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